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PROCEEDINGS

Sixth Meeting, First Half, 67th Session

The Sixth Meeting of the first half of the 67th Session of the Royal Aeronautical Society was held in the Lecture Theatre of the Royal Society of Arts, 18, John Street, Adelphi, on Thursday, December 10th, 1931, when a paper was read on "Air Flow," with demonstrations on the screen by means of smoke, by W. S. Farren, M.B.E., M.A., F.R.Ae.S., M.I.Ae.E. Colonel the Master of Sempill, Immediate Past-President of the Society, was in the chair.

The Chairman: The lecturer was well known to most of the audience. He would like to refer to his association with Professor Jones at the Aeronautics Laboratory in the department of engineering at Cambridge; the combination effected by Professor Jones and Mr. Farren was a unique and important one in the development of aeronautics in this country or, for that matter, in any other. Prior to Mr. Farren going to Cambridge, his career and association with aeronautics was quite a long one, as he started about 1915 and was engaged in experimental work and aerodynamic design at the Royal Aircraft Factory, as it was then called. After that for a period he was associated with Messrs. Armstrong Siddeley; he then went to Cambridge, and was not only busily engaged with the work there; but was concerned also—as he had been for many years past—with the activities of the Aeronautic Research Committee and its various sub-committees.

The lecture that evening was going to be of very great interest. It would be of great benefit to all of them, whether they were the very skilled experts or the casual observers.

He would like to pay a tribute to the Fairey Aviation Company, who had transported many items of apparatus from Cambridge without any cost to the Society.

AIR FLOW

With Demonstrations on the Screen by Means of Smoke

BY

W. S. FARREN, M.B.E., M.A., F.R.Ae.S., M.I.Ae.E.

Aircraft engineering has been described as "ordinary engineering made more difficult."[1] Probably most of you will agree that our difficulties are often greater than those that confront other branches of the engineering profession, and that the chief source of them is our inability to forecast with entire confidence what air will do under any given circumstances. Our position in this matter is much

[1] Prof. R. V. Southwell, James Forrest Lecture, 1930, Institution of Civil Engineers.

better than it was, for instance, at the end of the war. During the last thirteen years we have seen the theories associated with the name of Professor Prandtl receive general acceptance, with a profound effect upon our attitude towards some of the most important practical problems of air-flow with which we have to deal, namely, those associated with the production of lift. The boundary layer, then little more than a scientific curiosity, has become a matter of common concern. It achieved a striking practical success in the rationalisation of the international tests of airship models, which led to a marked advance in our attitude towards the whole problem of scale effect. But in many respects we are still greatly hampered. In so far as there has been any advance in the pure hydrodynamical theory of the flow of viscous fluids, it is hardly too much to say that its practical effect has been negligible. What then are we to do?

My own conviction is that there is nothing that can help us so much as a trained " air-sense ": we must become " air-minded." These phrases will not be unfamiliar to you, although my interpretation of them is different from that in common use. We must try to train ourselves to predict the behaviour of air in the circumstances which are of concern to us. I hold that it is quite unreasonable to expect to acquire such a sense except by deliberate effort. I have known many engineers of whom I can say no less than that they were inspired; men who seemed to be able to feel what was the right thing to do when faced with problems of this kind. More often than not they have been quite without theoretical training. Undoubtedly they owed much to an inborn faculty, but probably far more to experience, which they preserved unconsciously in minds of a special quality.

We must endeavour to find a way of acquiring this characteristic in some degree, and it seems to me that our most hopeful course is to study what air does by looking at it.

Unfortunately we cannot, in general, see very much in the conditions of actual practice—the air moves too quickly. But we now know enough of the nature of scale effect to enable us to interpret what we can easily see at low speeds, at least within certain limitations. We must be careful not to be misled by ignoring these conditions. I have said that our " air-sense " must be trained.

It is part of my work to train those among whom, I believe, many of the foremost aircraft engineers of the next generation will be found. In the Aeronautics Laboratory of the Engineering Department at Cambridge it has recently been the policy of Professor Jones and myself to teach not aeronautics merely, but what we term " Mechanics of Fluids," taking as illustrations all the ordinary problems of aeronautics, hydraulics and other allied branches of engineering. We have to resist a tendency, which, I am sure, will be excused here, to give too aeronautical a flavour to this course of teaching. We do our best to be fair, but every now and then we have to seek hurriedly for what are frankly less familiar, but more general, illustrations. Before the change in teaching arrangements took place which made this combination possible, I had experimented for some time, in aeronautics pure and simple, with methods of the type I have mentioned, with considerable success. In the wind-tunnel I have always insisted on the value of streamers of silk, etc., to make the flow visible, and on the advantages of apparatus of the type which intrigues the imagination rather than instructs the intellect. In the development of our teaching, the problem arose how to carry this out, in the more difficult atmosphere of the lecturing theatre, to an audience of one hundred to one hundred and fifty. It was solved by seeing Mr. L. F. G. Simmons's smoke tunnel, at the National Physical Laboratory, in June, 1930.[2] He was kind enough to give me full particulars of it, and I had

[2] A description of the apparatus and cinematograph pictures of some of the projections will be found in the Report of the Aerodynamics Dept. of the National Physical Laboratory for 1930.

one working in the following October. I should like to pay a tribute to Mr. Simmons as the originator of the idea of smoke pictures of this type on the screen.

I wish to digress for a moment concerning the connection between aeronautics and branches of engineering generally described as hydraulics. Such an idea is, of course, far from original, as is clear from the nature of the institutions controlled by Professor Prandtl at Göttingen, and of other similar institutions in some other countries. Be that as it may, we have throughout taken as our text the identity, within certain restrictions, of the problems which are dealt with in all the branches of engineering I have mentioned; problems which may be described under the general title of " the flow of fluids." Because it is more convenient at the moment, we illustrate our lectures only with demonstrations of the flow of air. We interleave these with lantern slides showing the flow of water in similar circumstances, as in fact I shall do this evening. Among other things, it gives the demonstrator breathing space. I have plans for showing the flow of water, which I hope to put into execution shortly. Such a policy in instruction in aeronautics appears to us likely to be the most fruitful for the advance of engineering generally. Aeronautics is remarkable for the high ratio between the volume of research work which is being, and has been, done, to its practical applications. That such research is capable of far wider application, if only the proper knowledge of it is widely disseminated, is a belief which I hope you will share.

From what I may, perhaps, term the historical aspect, the origin of the apparatus which I shall demonstrate to you is academic, to employ a much misused term. But all the time I was developing it (and you will see later that its form has been changed in the latest model, for reasons which I will explain) I had in mind that its real value might be far wider; that it might prove to be a means of investigating problems, or, at least, of suggesting lines of investigation; in short, that it might become a convenient means of keeping one's " air sense " in training. In this I have had some success. I have, indeed, been able to persuade engineers of widely-different interests of its usefulness. It is not expensive. Excluding the projecting lens, the complete outfit of the size I use can be made for about £65.

The apparatus, when developed, had one characteristic which I confess I had not entirely anticipated. It proved to be a source of entertainment to audiences of very varied composition. I do not know that there is any particular disadvantage in being entertained while you are being instructed. At any rate, there does not seem to be any complaint on this score from those who attend our lectures in which it is used.

In closing this introduction I would make one remark. The side of aeronautics with which I am concerned at the moment has long been the playground of the applied mathematician. I trust I shall not be considered to be casting any reflection on the attainments of so distinguished a class, among whom, of course, I am quite unqualified to be placed. I have complete confidence in their ability to produce the solution eventually. My difficulty is that I am in a hurry. This must serve as a partial excuse for what some of you may feel to be reducing such a serious subject to the level of a picture show. For the rest, I would quote in my defence the remarks of Sir Joseph Thomson, written in connection with the recent celebrations of the Centenary of the birth of Clerk Maxwell: " No man ever appreciated more highly the advantage obtained in concentration of thought and in the influx of new ideas by considering a concrete case like a model, instead of relying entirely upon algebraic symbols. He said, in an address to the British Association in 1870, ' For the sake of persons of different types, scientific truth should be presented in different forms, and should be regarded as equally scientific whether it appears in the robust form and the vivid colouring of a physical illustration or in the tenuity and paleness of a symbolical expression.' "

Interpretation of Observations—Limitations of Methods

The Reynolds number characteristic of such flows as can be observed in any detail in the apparatus I shall demonstrate is low. The highest speed at which anything of the nature of turbulent flow can be followed is about five feet per second, representing a Reynolds number (based on the tunnel diameter) of 10^4. The boundary layer on smooth stream-line shapes in such conditions is probably mainly laminar, and quantitative observations (*e.g.* of the point of break-away of the flow) could not be regarded as applicable to full-scale practice. But qualitative observations of cases in which there is gross turbulence, including the effect of measures intended to reduce or remove it, would seem to be trustworthy, especially when examined critically in the light of our now considerable knowledge of scale effect. I shall show some examples illustrating this point. It is naturally the most important consideration in relation to the use of the apparatus for the solution of practical problems.

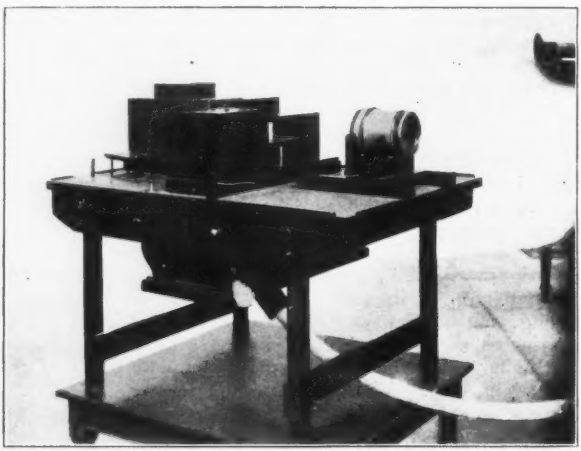


FIG. 1.

General view of smoke tunnel.

On the other hand, from the point of view of the use of the apparatus for demonstrating the fundamental features of fluid flow, the available range of Reynolds number could hardly be more fortunate. For example, the most striking changes in the character of the flow round a circular cylinder occur between R = 10 and R = 1,000 (based on the diameter). This can be covered with cylinders of several sizes.

Owing to the high density of the " smoke " used, it is not possible to produce good effects at very low speeds. But the phenomena characteristic of the sudden generation of flows from rest can be demonstrated.

Description of Apparatus

The wind-tunnel I use for projecting smoke pictures on to a screen has a closed working section 3in. × 3in., with glass sides 8in. long. This occupies virtually the position of a lantern slide. The models used are generally, but not always, two dimensional, and the flow is maintained by an exhaust fan and is controlled by two throttles, one of which can be opened and shut suddenly in order

to examine the conditions when the flow of air starts or stops. To make the flow visible titanium tetra-chloride is introduced, sometimes on the surface of the model and sometimes in the stream. The use of titanium tetra-chloride for this purpose is now fairly general, and its disadvantages as well as its advantages are becoming gradually better realised. It undoubtedly gives a very dense smoke and has the convenient feature that a drop of liquid placed on the surface of the model will evaporate fairly slowly. The fact that the vapour contains hydrochloric acid is a disadvantage, but I have found in practice that, with suitable precautions, it can be overcome. By avoiding as far as possible the use of metal in the tunnel the actual apparatus does not suffer, and by passing the air from the tunnel through a gauze soaked in a weak solution of ammonia the exhaust may be rendered hardly more objectionable than tobacco smoke. In view of the low speed in the tunnel, and the consequent small differences of pressure involved in the flow, it is desirable that the final exhaust should not be out-of-doors.

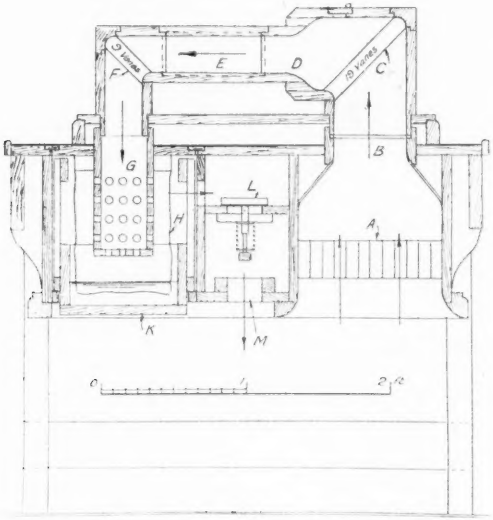


FIG. 2.

Arrangement of smoke tunnel.
(Cross section in vertical plane containing central plane of working section.)

The arrangement of the tunnel is shown in Figs. 1 and 2. The base of the apparatus is a box approximately 3ft. long, 12in. deep and 12in. wide. One end of this contains a honeycomb (*A*) 12in. × 12in., through which the air passes vertically. It is contracted at (*B*) to 6in. × 6in. and turned through 90° by vanes at (*C*). At (*D*) it is contracted to 3in. × 3in., and passes to the working section (*E*) round another 90° bend at (*F*) into the other end of the base, which contains the device for removing the acid. This consists of a perforated box (*G*) surrounded by a gauze curtain (*H*), which consists of one layer of butter-muslin between two of stiff gauze. The gauze dips into a wooden tray (*K*) containing a solution of ammonia. After passing through the gauze the air passes through a throttle (*L*), in the central part of the base, and from this to the exhaust fan by a 2in. rubber pipe at (*M*).

Various types of fan are used, according to requirements, but a very simple one seems to be quite effective for all ordinary purposes and is shown in Fig. 3. The rotor is driven at speeds up to about 1,500 revolutions per minute by a motor whose speed is controlled by a rheostat arranged as a potentiometer.

The whole of the tunnel and fan, with the exception of the vanes (*C*) and (*F*) and the shaft and bearings for the rotor, is of woodwork. I should like

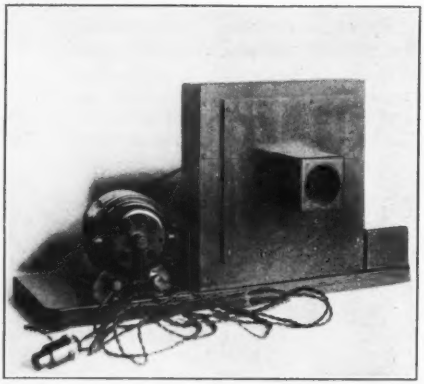


FIG. 3.

Exhausting fan.
(Rotor 8in. diameter, 1in. wide, surrounded by volute chamber.)

to take the opportunity to pay a tribute to Mr. W. C. Carter, of Cambridge, in whose works it was made: Mr. Carter has been indefatigable in co-operating with me in the development of the apparatus. I can only say that it is often admired as much for the beautiful workmanship in it, as for its other qualities.

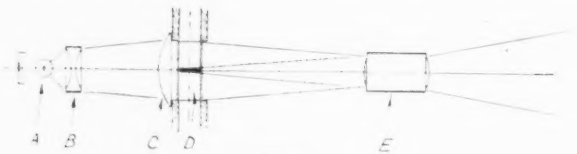


FIG. 4.

Optical system.
(A 250 watt lamp, B 6in. condenser 6½in. F.L., C 10in. condenser 13in. F.L., D working section, E projecting lens.)

The optical arrangements are simple and are shown in Fig. 4. An ordinary 250-watt metal filament lantern lamp (*A*) is used. The light passes first through a 6in. condenser (*B*) of 6½in. focal length, and then to a 10in. condenser (*C*) of 13in. focal length. This is directly in contact with one side of the working section (*D*) and converges the light through the tunnel to the projecting lens (*E*). For the latter we are fortunate to have a 70 centimetres F 5.0 Zeiss aeroplane camera lens. Such an expensive lens is not absolutely necessary. For use in a room of ordinary size any reasonable lens of about 3in. aperture will give a

sufficiently good image for most purposes. It is only when it is necessary to project in a large room that a high-quality lens is needed. Owing to the depth of the tunnel in the direction of the optical axis the models themselves are generally not in focus, but in practice this has not proved to be a serious disadvantage. In the ordinary way the central plane of the tunnel is in focus, and with care the image on the screen can be made very sharp.

Models

The models used vary greatly in character, and there is room for considerable ingenuity in devising novel forms. For anything in the nature of a demonstration it is naturally necessary that they should be quickly interchangeable. A con-

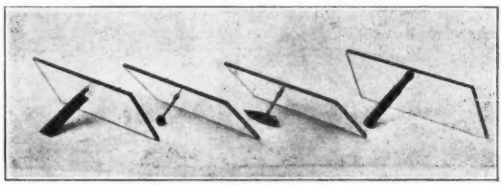


FIG. 5.

Models supported on glass, interchangeable with side of tunnel.
(Aeroplane wing, sphere, R.101, rotating cylinder.)

siderable number, particularly those relating to the flow of air round isolated bodies, are mounted on separate pieces of glass which can be lifted out, forming one side of the working section. Holes are drilled through the glass in suitable places and the models are supported as shown in Fig. 5, this making it possible to change their attitude from outside. Both two and three-dimensional models can be conveniently supported in this way. I have, however, gradually abandoned this type of support, partly owing to the difficulty of dealing with glass, and now mount each model on a separate piece of wood interchangeable with the lid of the working section as shown in Fig. 6. These are particularly suitable for what may be termed pipe problems, that is to say, anything of which the essential feature is the walls which constrain the flow. Three-dimensional models of this type are naturally more difficult to manage, but by the use of internal walls of celluloid a great deal can be done. Fig. 6 includes two such models.

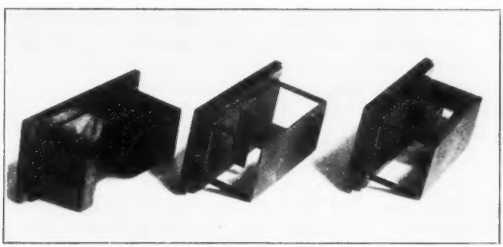


FIG. 6.

Models supported on wood, interchangeable with lid of working section.
(Pipe of varying shape but constant cross section, sharp-edged orifice (two-dimensional), contraction or enlargement in pipe (three-dimensional).)

It is not necessary that models, especially of the second type, should be entirely fixed in shape. There are shown in Fig. 7 three examples of models which contain moving parts. It is not difficult to imagine that these have proved the most popular type.

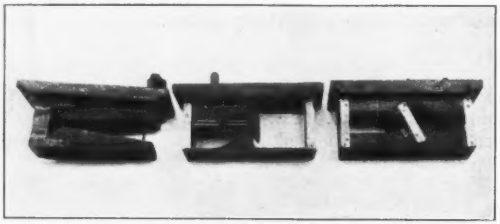


FIG. 7.

Models with moving parts.
(Venturi tube, adjustable angle of expansion, poppet valve, carburettor with barrel throttle.)

Method of Producing "Smoke"

The technique of using titanium tetra-chloride is one that has to be learnt by somewhat bitter experience. My own practice is to use glass rods drawn down to the shape shown in Fig. 8. These are dipped into the liquid, a small quantity of which is contained in a fairly large glass-stoppered bottle. The glass rod is inserted in the tunnel through holes drilled in suitable places, and it is important that these should be closed after removal of the rod, or, if the rod is held in place, that a small plug of cotton wool should be held against the rod where it passes through the hole. If this precaution is not observed, the flow in the tunnel may be considerably disturbed by air coming through the holes; on the other hand, it is not necessary that the holes should be completely filled, the presence of a cul-de-sac in the tunnel wall being apparently of no great moment.

A little experience will show that the " smoke " varies considerably in colour and density, and I have found that this is due to a variation in the state of the titanium tetra-chloride liquid. The best effects are produced when the liquid is fresh. If it is kept free from contact with air it keeps quite clean, but in the presence of any appreciable quantity of air solids begin to form which may be picked up by the glass rod when dipped into the liquid. For a good effect it is necessary to avoid this, and, moreover, to keep the end of the glass rod quite clean by wiping it every time it is withdrawn from the tunnel.

FIG. 8.

Glass rods used for introducing titanium tetra-chloride into tunnel

A great deal of trouble can be saved by judicious use of paraffin wax, both on every part of the woodwork with which the titanium tetra-chloride comes in contact, and on the neck and stopper of the glass bottle used to hold it. Great care should be used to keep everything as dry as possible, as the reaction of titanium tetra-chloride with water is extremely rapid and produces solid deposits which are very troublesome.

These remarks are intended rather to help anyone who attempts to use an apparatus of this type over the first few disappointments. The details of the technique are best discovered by practice, and probably everyone will develop one which suits him comparatively rapidly.

When the apparatus is used for illustrating lectures a considerable amount of time must be lost in between demonstrations, however well arranged the models may be. To avoid this it is convenient to be able to interleave lantern slides with demonstrations, particularly, as I have mentioned above, those showing the flow of water in similar conditions. With a little ingenuity of arrangement one may easily contrive switching arrangements which enable this to be done with no loss of time.

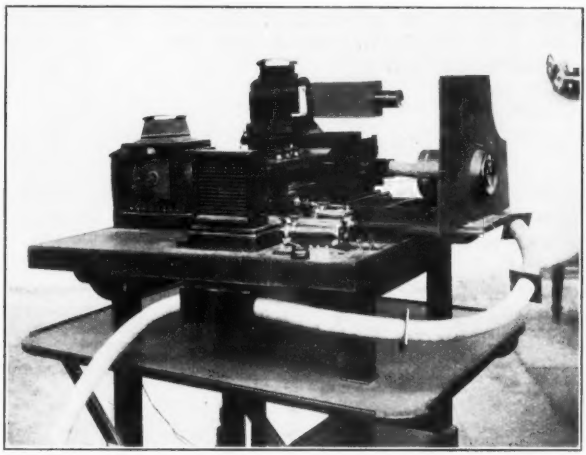


FIG. 9.
Original form of smoke tunnel.

Development of Apparatus

It may be worth while recording my reasons for the change I have made in the apparatus from the original form devised by Mr. Simmons. I adopted Mr. Simmons's arrangement in the first model I made, which is shown complete in Fig. 9. This is, in fact, the one we have used hitherto in lecture demonstrations. Apart from points concerned with convenience and compactness, it differs from the later type, which I have already described, in two essential features. First, the flow is produced by a fan arranged as in an ordinary N.P.L. type of tunnel, the speed being controlled from the motor. Second, the air enters horizontally. The first feature has the disadvantage that rapid changes in speed cannot be produced. A throttle on the exit is fairly successful, but when this is shut the fan produces turbulence in the working section. The second feature results in disturbance of the entering air by movements of the operator's body. The later type avoids these disadvantages. Moreover, on account of the greater contraction of the air-stream, the flow through the tunnel is much smoother.

If it is desired to project the flow on to a screen (and for all two-dimensional conditions there are many advantages in this course), the size of the tunnel is limited mainly by the cost of the optical arrangements. With those described above, it would be possible to have a working section 6in. deep by 9in. long. The tunnel could, of course, be wider than 3in., but any great increase in this

dimension makes projection less satisfactory. On the whole, I think that the dimensions just mentioned, combined with a width of say 4½in., are a convenient compromise, and result in a piece of apparatus which is of a size suitable for use both for demonstration purposes and for the wider uses to which I have already referred. My only reason for keeping to the original size (3in. × 3in.) in the second tunnel is that I wished to be able to use the large number of models I had already made for the first one.

List of Demonstrations

The demonstrations will illustrate the following points:—

(1) The nature of viscosity and some characteristics of the boundary layer.
(2) The variation of flow pattern with change of Reynolds number.
(3) The initial stages of flow started from rest.
(4) The generation of lift.
(5) Flow breakdown.
(6) Flow control.
(7) Application of method to some practical problems.

The accompanying photographs are enlargements from a 16 mm. cinematograph film of the demonstrations shown in connection with the paper. In certain cases it has been found necessary to strengthen the image of the smoke on the picture by means of pencil, as it is difficult to obtain a density of smoke high enough to make a clear photograph in all cases.

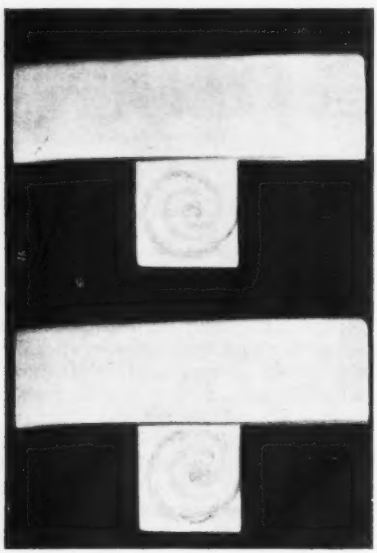


FIG. 1.

Experiment illustrating the nature of fluid viscosity. The flow in the "cul-de-sac" is maintained by the action of viscosity. The motion consists of a continuous rotation, combined with a small but steady mixing of the stream of air passing above the "cul-de-sac" with that inside it.

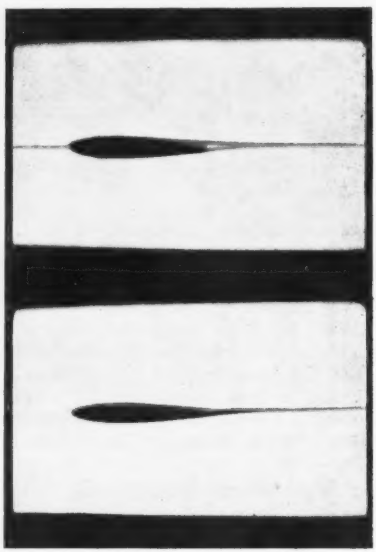


FIG. 2.

Flow past a smooth streamline shape showing the boundary layer maintaining contact over practically the whole length. (The detachment of the smoke in the upper photograph is largely due to the high density of the smoke. Note that the photographs are inverted.)

Discussion

Professor L. Bairstow (*Fellow*): He would like to express his appreciation of Mr. Farren's great skill in carrying out these experiments before the Society, with apparatus which had to be brought up from Cambridge and rigged up under temporary conditions. In addition, Mr. Farren had shown a great deal of skill in producing the apparatus in the first place in a form which was suitable for lecture demonstrations. He would not mention different methods of illustrating fluid motion, because there were several people in the room who had more first-hand knowledge and who would probably speak themselves, but it was a fact that there were now several promising methods. A stage in the history of the development of aero-science and practice had been reached at which they were realising more and more the need for seeing what was going on.

One of the slides that had been shown—the last of what Mr. Farren called the serious part of his lecture—had been made at the National Physical Laboratory and was the result of a long series of detailed observations; the result—the establishment of the amount of circulation round an aerofoil justified the extensive labour and for some purposes that no doubt similar labour would still be necessary, but if one had photographs which could be obtained from Mr. Farren's apparatus before starting measurements, a good idea would be formed as to what one had to measure. If it were possible to carry Mr. Farren's experiments further, to the three dimensional case and find what was happening on a spinning aeroplane, there was little doubt that our troubles in curing difficult spins would be very much reduced. That was the more immediately practical view, but there

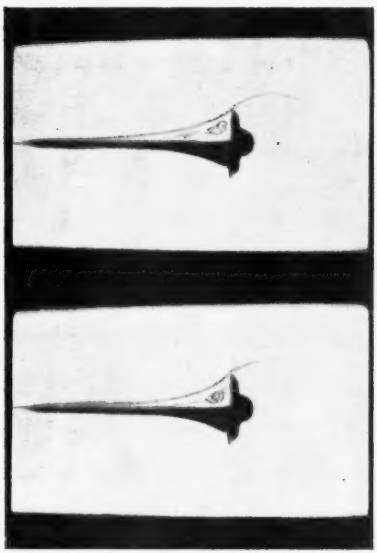


Fig. 3.

Boundary layer on a thin flat plate forced to break away by the pressure system of a flat plate at right angles to the stream. Note the eddies formed in the corners between the two plates. These are continuously fed by the fluid from the boundary layer. Viewed in the other direction they are of helical form, their contents being discharged over the edge of the transverse plate where this meets the tunnel walls.

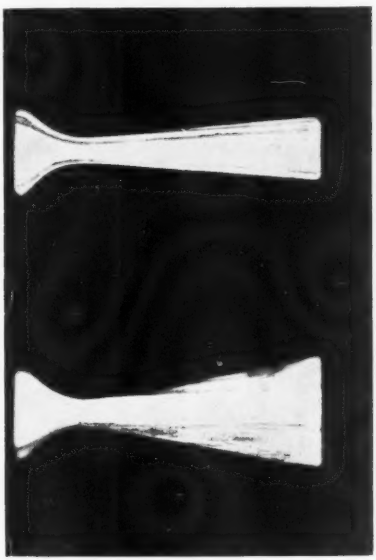


Fig. 4.

Flow in a Venturi tube. Above: diverging passage flowing full. Below: angle of diverging passage increased, flow no longer clinging to walls, rapid increase of pressure causing boundary layer to break away practically at the throat.

were quite a limited number of people in the world who were interested not only in seeing what happened but in explaining what happened so as to be prepared for the practice of the future. Why, for instance, did the boundary layer round an aeroplane break away at an angle of incidence of 15 or 20 degrees? So far as the speaker knew there was no acceptable explanation—they merely knew that it did. A student of the Imperial College who is now in Canada had tackled that problem to see whether the Prandtl boundary layer theory (the mathematical theory) could account for what the smoke did round a circular cylinder. The speaker thought that up to the breakaway the theory applied. Another student at the Imperial College was carrying on in the hope of explaining what happened after the breakaway.

Mr. Farren that evening had only touched on the fringe of a subject of the very greatest importance to the future of aeronautics. Many aeronautical problems were far too complicated to work out by simple mathematical rules.

Mr. HANDLEY PAGE (*Fellow*): He was not sure whether he ought to speak as this was a serious scientific paper, and according to Mr. Farren he belonged to the non-serious part. Why he was not sure, because it seemed to him that in the latter part of Mr. Farren's paper the author had given some very good illustrations of the way in which air flow could

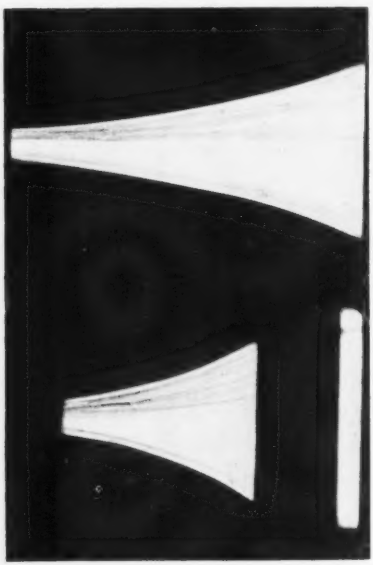


FIG. 5.

Flow in passages of constant cross-sectional area. The shape of these passages is such that the cross-sectional area is constant throughout. The shape viewed in a direction at right angles to that shown is seen by turning the photographs through 180°. In neither case is there any sign of breakaway of the boundary layer from the walls, in spite of the curvature of the surface. The flow appears to be entirely free from eddies. The average pressure along the stream is constant, but there are, of course, considerable transverse differences of pressure at any cross-section.

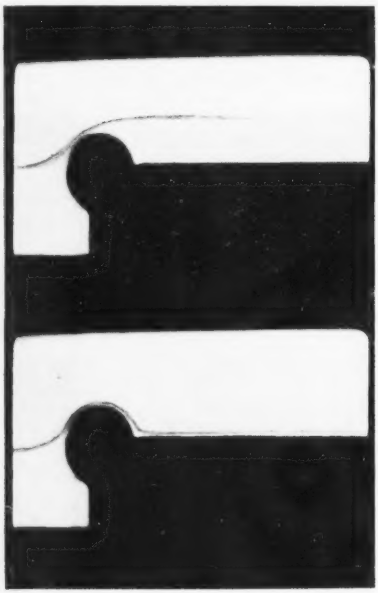
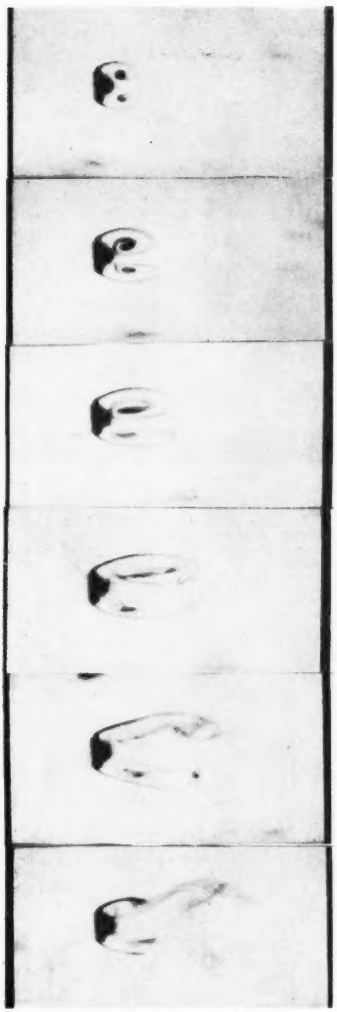
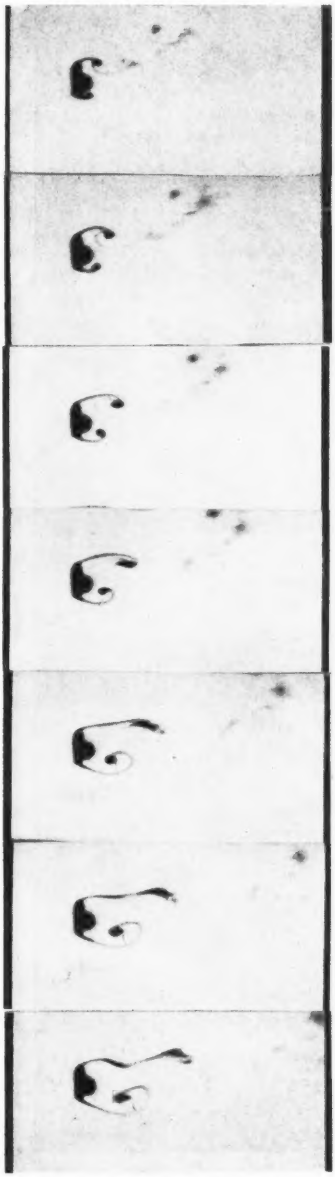


FIG. 6.

Breakaway of boundary layer round circular cylinder prevented by rotation. The lower half of the picture is provided with a guard which can just be seen in the photograph, reaching to the foremost point. There is a passage for the air past this guard, below the plate, downstream of the cylinder. Above: cylinder stationary, flow breaking away. Below: cylinder rotating, flow clinging to the cylinder over whole of upper surface. No sign of turbulent motion in whole of space above and behind cylinder





FIGS. 7 and 8.

Generation of flow past flat plate at right angles to stream. Fig. 7 shows the flow resulting from starting the motion as rapidly as possible. Note symmetrical eddies degenerating into unsymmetrical flow. Fig. 8: motion started less rapidly. Unsymmetrical character of flow occurring almost from start. Interval between pictures approximately one-twelfth second.

FIG. 9.

Generation of flow through a sudden enlargement. In initial stages a two-dimensional "smoke ring" appears. This lengthens out as shown in lower pictures, final flow being a jet with turbulent region outside it.

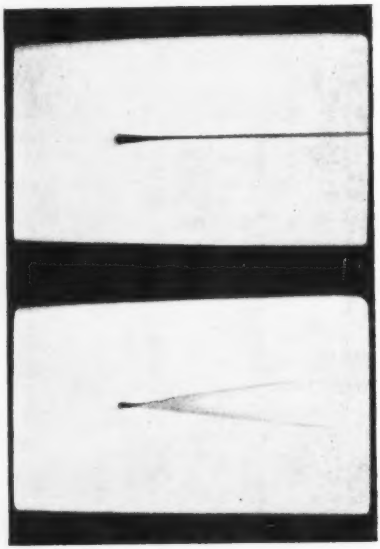


FIG. 10.

Breakdown of viscous flow past circular cylinder with rise of Reynolds number. Above: viscous flow. No sign of eddying outside small region immediately behind cylinder. Below: turbulent wake behind cylinder at slightly higher speed.

FIG. 12.

Flow past same cylinder as in Fig. 11 at higher speeds.

FIG. 13.

Flow of Fig. 12 stopped suddenly, showing eddies forming turbulent wake.

FIG. 11.

Fig. 11: Speed gradually increasing. With larger cylinder change takes place at slower speeds and processes can be followed. Note gradual increase of size of turbulent region immediately behind cylinder and tendency of trailing wake to become wavy in form, degenerating into eddies. Reynolds number corresponding to change in type of flow approximately 100 (using diameter as characteristic length).

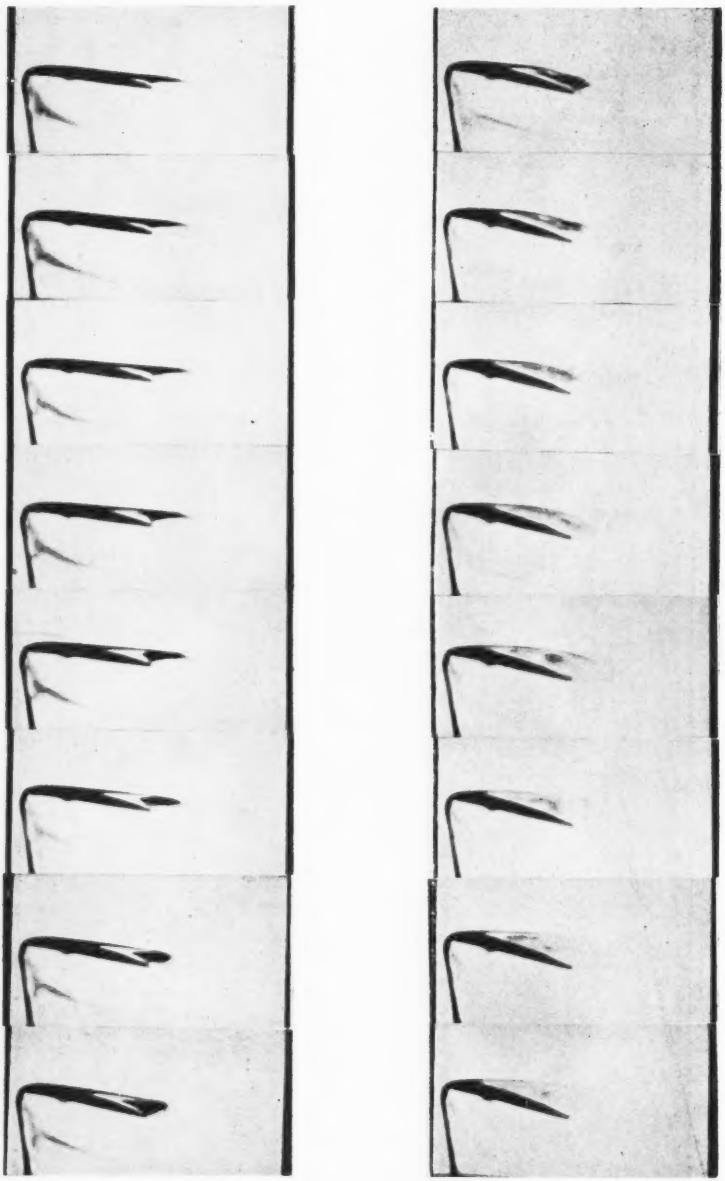


FIG. 14.

Change of flow past aerofoil as angle of incidence is increased, speed remaining constant. The object below the leading edge of the wing is the rod by which its angle of incidence was changed. Note backward flow along upper surface. There are indications that at the low Reynolds number of these experiments the wing begins to stall at a lower angle of incidence than at higher Reynolds numbers, but the general character of the change is probably unaffected. Interval between photographs approximately one-twelfth second.

be studied and used from a practical point of view. Particularly interesting was the demonstration of air flow through a motor car, because they had found that the use of a similar method had enabled them to determine the flow of air through the fuselage of an aeroplane. This was an important point to be considered when dealing with the openings in an aeroplane, such as occurred at the bomber's prone position where one had to look down through an aperture at the object of attack, and through that aperture very considerable draughts often came which had to be eliminated. A study of the air flow through the fuselage by the method Mr. Farren had shown to them this evening formed a very good means of trying out and preventing unnecessary air flow through the fuselage.

This test, the speaker thought, formed an answer to one of the questions Mr. Farren had raised as to the way in which this method of studying air flow could be usefully employed in ordinary aeroplane work.

The speaker said that he wondered whether full advantage had been taken of this research work in relation to the flow of air and gases in pipes. It seemed to him an excellent demonstration of the way in which the air or gas could be

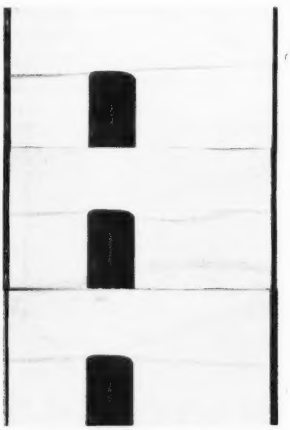


FIG. 15.

Flow past wing tip seen in plan. Above: flow just below tip showing outward movement of streamlines. Middle: flow just behind wing tip showing centre of trailing vortex. Below: flow just above wing tip showing inward movement of streamlines.

FIG. 17.

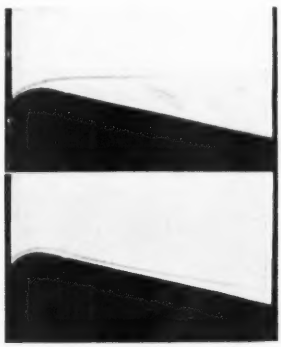


FIG. 16.

FIG. 18.

FIGS. 16, 17 and 18.

Control of flow by removal of boundary layer by suction. Fig. 16—Above: flow breaking away after sudden obstruction. Below: breakaway prevented by removal of boundary layer at slot. Motion over whole of stream eddy-free. Figs. 17 and 18: effect of removal of boundary layer from upper surface of stalled wing at two different angles of incidence.

diverted round a tube without constriction of the flow, and that it might have a very useful application in ordinary gas or compressed air distribution: one should be able to obtain a very considerable decrease in the pressure required to drive the gas along its desired course. He wondered whether Mr. Farren could tell them if any practical application had been made of that part of the study of air flow.

Mr. RELF (*Fellow*): In his opinion the apparatus could be put to direct practical use. For example, if the places were found where the flow was disturbed near, say, a body-wing combination, and these places were faired until the flow indicated by the smoke was smooth and free from eddies, he felt that the result on the full scale was unlikely to be different, *i.e.*, a well streamlined combination at the low Reynolds number would probably be even better at high Reynolds numbers. For this reason he thought that designers would find the apparatus very useful, and if a number of people wanted to purchase such apparatus the cost of making it might be reduced considerably.

Mr. Farren had shown very clearly the well known fact that bluff bodies give rise to a streamline flow at very low Reynolds numbers which breaks down into an eddy flow at higher Reynolds numbers. The speaker once demon-

FIG. 19.
Flow round 90° bend in pipe. Above: turbulent flow at corner caused by break-away. Below: eddy-free flow produced by guide vanes at bends.

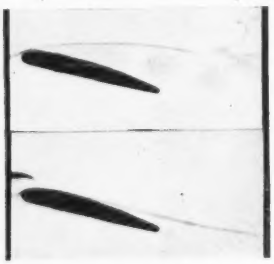


FIG. 20.
Stall of wing prevented by auxiliary aerofoil in front of leading edge. (Handley Page.)

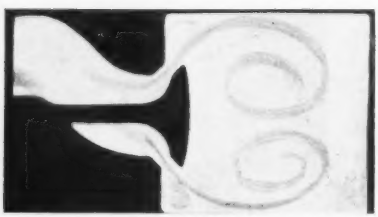


FIG. 21.
Flow through inlet valve when suddenly opened.

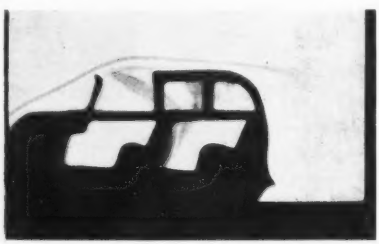


FIG. 22.
Flow past motor car showing effect of suction above roof, combined with leaks in floor of rear part, producing draughts.

strated this fact in rather a pretty way, and as the result had not been published, he thought it might be of interest to mention it now. A wire about 0.05 inch diameter was stretched across a wind tunnel and about half an inch behind it was placed a hot wire anemometer connected through a valve amplifier to telephones. By this means it was possible to hear the eddy frequency produced by the wire as a musical note. If now the tunnel motor was stopped so that the wind speed in the tunnel dropped rapidly, the note heard dropped in pitch, but at a certain pitch ceased abruptly. On starting the wind tunnel again the note recommenced to sound at the same pitch at which it had previously ceased and then rose in pitch as the wind speed further increased. When the wind speed at which the sound ceased or commenced was measured, it gave a Reynolds number of about 100 as the value at which eddy motion commenced, thus agreeing with the result of visual observations such as had been demonstrated to-night.

Mr. McKinnon Wood (*Fellow*): Mr. Farren had developed a very useful piece of apparatus for the purpose of lectures to students of engineering, and of aeronautics in particular. He agreed with Mr. Relf in thinking that some such apparatus would have a wider use and be valuable to designers and to those who are engaged in aeronautic research. Many had in the past tried to visualise air flow but found it difficult to get satisfactory results. One of the things that interested the speaker particularly about the demonstrations that evening was the beautifully fine streamline that Mr. Farren produced. They had been up against this trouble in the past that disturbance of the stream in introducing smoke had caused the streamline to spread out and fade away. No doubt there was a good deal gained by introducing smoke at a point where the air was moving slowly, so that the disturbance would be small and the trail of smoke would contract from its original size.

Mr. Simmons (National Physical Laboratory): He had taken the trouble that morning to look up the records and found that smoke experiments were first started there in the year 1911. Since that date and for 17 years afterwards there was hardly a reference to smoke experiments. It was true that on occasions certain experiments were made with chemical smoke for the purpose of getting a better photograph—smoke formed by mixing ammonia and hydrochloric acid vapours together. It was found that even under turbulent conditions it was very much better than the smoke previously used; but it was not until about three years ago that titanium tetrachloride had been tried, which proved even better and persisted for much longer under wind tunnel conditions. The application of this method had been largely developed by the lecturer, and the speaker wished to express his admiration for Mr. Farren's ingenuity. Mr. Farren had said that the visual method should prove a useful acquisition, especially in connection with the development of air sense. It was very necessary—and he was sure Mr. Farren would agree—that these experiments should be carried further to higher Reynolds numbers. For that reason he would like to see established a very much larger wind tunnel, set apart specially for experiments of that kind; a tunnel designed on the lines of, say, Professor Taylor's non-turbulent wind tunnel at the N.P.L.; or, alternatively, some kind of liquid tunnel in which special precautions were taken to maintain steady flow.

Mr. Townend (*Associate Fellow*): He had not come prepared to make any remarks, except perhaps to congratulate Mr. Farren, not only on the excellence of the stream of smoke he had produced, but also on the ingenuity of his various models. There was one model which rather interested him. That was the model in which there was a divergence in one plane and a convergence in a plane at right angles, the area of cross section being constant. It struck the speaker that in this there was a real discrimination between the effects of a pure divergence and the effects of a pressure gradient. On second thoughts he was inclined to think that Mr. Farren was possibly a trifle unfair, because he only showed one side of that picture; if he had shown the other side, that is to say, the side at

right angles, they would have seen a convergence; so perhaps it was not quite fair to call it a divergence any more than a convergence. From a purely aerodynamic point of view it seemed that since the area was constant, it might not be permissible to consider the divergence apart from the convergence and hence to infer that the flow was stable because the pressure gradient was zero. One might easily take the other point of view, except that since convergent flow never was unstable, there would be nothing to discriminate between.

Mr. M. L. Bramson (*Fellow*): Were they to understand that the reasons for the break away of the boundary layer were not known or recognised? It might be gathered from the discussion that the reason was always the fact that the boundary layer had to move against an adverse pressure gradient, which meant, no doubt, that if the pressure gradient were sufficiently steep to overcome the energy of the boundary layer before it reached the trailing edge of the body, then the boundary layer was decelerated, stopped and finally had to break away while it was still in contact with the body. The speaker wished to know if that was a correct qualitative statement of what occurs at the stall. Dealing with Mr. Handley Page's remarks as to the connection between aerodynamics and other forms of technology, the speaker thought Mr. Handley Page referred mainly to the flow of air in pipes. There was, however, another very large branch of engineering, namely the technology of heat exchange. That was also completely dependent on boundary layer flow, and it seemed to the speaker that the time had now come when the experience of aerodynamics might be applied to the improvement of the methods of dealing with the processes of heat exchange. These were of especial importance in chemical engineering. The essential feature seemed to be that whereas in aerodynamics one was concerned with removing the nuisance of the breakaway of the boundary layer, in the problems of heat exchange one was trying to force the boundary layer to break away, because the boundary layer was the main obstacle to heat exchange. For that reason (it seemed to the speaker) Mr. Farren's apparatus might with advantage be used to find out how one could make boundary layers—if they were reluctant to do so—break away when wanted.

Mr. J. L. Hodgson (*Associate Fellow*): He had used methods involving what was now known as the Reynolds criterion for a considerable time. It was just twenty-one years since he had sold his first orifice-type steam meter which was calibrated with water, and which was able to measure steam flows to within one per cent. of accuracy. In 1908, when the research on which that meter was based was commenced, the possibility of successfully calibrating a meter with a liquid and using it for the measurement of a gas was by no means obvious.

Up to the present the speaker had had to work very much in the dark with regard to the behaviour of streamlines. He considered that Mr. Farren's convenient and easily manipulated apparatus would put an end to difficulties due to this cause.

The speaker dealt with an interesting effect which perhaps Mr. Farren had not observed, namely that the coefficient of discharge of an orifice at first increased as the flow was gradually reduced from a high to a low Reynolds number, and this, in spite of the fact that the effects of viscosity became of relatively more importance as the Reynolds number diminished. The theoretical explanation of this phenomenon which he had put forward was that the first effect of viscosity was to absorb the momentum of the particles converging through the orifice and so actually to increase the coefficient of contraction, and so the coefficient of discharge. This explanation could be immediately proved or disproved by means of Mr. Farren's apparatus.

Another interesting orifice effect that Mr. Farren's apparatus could have quickly elucidated was that a particular orifice on test gave over certain ranges of Reynolds numbers an unduly high coefficient of discharge, and in addition caused a whistling in the main. It was deduced that this effect was due to the

period of eddy formation on the downstream side of the orifice plate agreeing with the natural periods of vibration of the plate. The effect was eliminated by stiffening up the plate.

Referring to Mr. Handley Page's question as to whether the method of conducting air round bends which Mr. Farren had shown, was used by engineers, the speaker could say that for many years the designers of turbo-blowers had used this method.

With regard to the apparatus itself, the speaker said that there were two respects in which he would like to alter it; to obtain continuous streamlines, and to work at higher Reynolds numbers. As far back as 1910 he had designed and used a closed high pressure air circuit working up to pressures of 100lbs. per square inch—thus increasing the Reynolds number about $7\frac{1}{2}$ times. There was no difficulty in making glass windows to stand the above pressure. This circuit, which is capable of circulating about one ton of air per minute, now formed part of the standard air meter testing plant of South Africa, and it was interesting as being a forerunner of the high pressure wind tunnel installed recently at the N.P.L.

Air Commodore CHAMIER (*Associate Fellow*) (*communicated*): Mr. Farren asked if his instrument was of practical value to aircraft constructors. In so far as it creates vision and stimulates the imagination, the answer is an emphatic "Yes." But its immediate practical value appears to be dependent on the question of the Reynolds number. They knew only too well that small wind tunnels operating at low Reynolds numbers (but yet much higher numbers than they could get in the small smoke tunnel) often deceived them; the air, in fact, is apt to behave in a vastly different manner at full scale. Was not that motor car going at less than a mile an hour when no eddy came in over the top of the wind screen?

On the more serious side they saw in this slow speed air that the wing gradually stalled by the spreading of the burble from the rear forwards. Is it possible that high speed air might rebound off from the nose without any gradual breakaway from the trailing edge? One has an uneasy feeling that this uncertainty must be dispelled if they were not to be led sadly astray.

Again, many of their worst problems are problems of three-dimensional flow, *e.g.*, the interference of a body and a wing and it is difficult to see three-dimensional flow on the screen, apart from such factors as tunnel wall interference.

The CHAIRMAN, before calling upon Mr. Farren to reply, said he would like on behalf of the Royal Aeronautical Society to congratulate him on his lecture and demonstration; also on the work that he had been doing at Cambridge and elsewhere since he last appeared before the Society, when he read a heavily discussed paper, "The Monoplane versus the Biplane." In regard to his work that evening, the speaker felt quite sure that it was going to have a very wide application in various directions, and thought they would hear a great deal more about it.

REPLY TO DISCUSSION

Mr. FARREN: He did not think there was much which had been said which called for reply. As Professor Bairstow had said, there were other ways of making shadow pictures of air flow. He hoped to use the Townend hot-wire method in his apparatus. He also had plans for taking cinema pictures of the smoke pictures in order to provide a permanent record of them.

In regard to the question of vanes in pipe bends referred to by Mr. Handley Page, the demonstration undoubtedly showed their effect in a convincing way. The arrangement he had shown had been in common use for years in wind tunnels, but had not been widely used outside aeronautical circles. He believed it was originated by Prandtl. It seemed that without it a closed circuit wind tunnel would be out of the question, since no alternative scheme produced an even approximately uniform stream. From the point of view of power economy in

flow of fluids through pipes its essential application was where the kinetic energy was high in comparison with the frictional losses—for instance, in the cooling ducts of transformers, where the main loss was in the bends. The loss at a 90° bend was from 5 to 10 per cent. of the kinetic energy of the air when vanes were used, compared with about 100 per cent. for a sharp corner without vanes.

Mr. McKinnon Wood was right as to the fine streamlines. The " smoke " was put in on a glass rod, as shown in Fig. 8, at a place where the cross-sectional area was large, and the speed below that at which the flow past the rod was turbulent. The subsequent contraction made the streamline still finer. If the speed were raised above this value the eddies coming off from the rod made the streamline blurred.

The lecturer entirely agreed with Mr. Simmons' remarks. A wind tunnel ought to be constructed specifically for visualising. The methods involved seldom agreed well with delicate apparatus, such as balances. In any case the importance of the work was itself sufficient reason.

Mr. Hodgson's remarks were very encouraging. With regard to continuous streamlines, his experience was that, although everyone had ideas about suitable substances for making smoke, nothing had so far been suggested which was as good as titanium tetrachloride, particularly for projection. The only trouble with it was its effect on metal.

In reply to Mr. Townend, it was true that there was no change in the cross-sectional area of the stream in the demonstration to which he referred, but the whole point was the shape of the walls—they were highly curved (progressively more and more curved in the successive examples shown) and it was not possible to force the stream to break away. A good deal had been made of the possible differences between the boundary layer on a flat surface and that on a curved one, but it did not seem that there was any very substantial difference.

In regard to the cause of the breakaway of the boundary layer (and here he would reply also to Mr. Bramson), while it might be rash at the moment to express any definite opinion, it seemed difficult to avoid the conclusion that the primary cause was the rise of pressure down the stream at a rate in excess of some critical value. The demonstration he had shown in which the boundary layer on a flat plate arranged tangential to the stream was caused to break away by the presence of another plate at right angles to the stream illustrated this. Had the boundary layer been absent the stream would have been brought to rest (at any rate nominally) at the centre of the transverse plate, the pressure there rising to the pitot tube value. This was shown when the tangential plate was removed. When both were present together the pressure system of the transverse plate combined with the frictional force of the tangential plate resulted in the stream being brought to rest *before* it reached the transverse plate, as was clear from the reverse in flow at the point in question and the formation of the conspicuous eddy in the corner. He had observed these transverse eddies, which had a strongly three-dimensional character, near the trailing edge of an aerofoil.

In reply to Air Commodore Chamier's communication, undoubtedly the low Reynolds number characteristic of the apparatus is a drawback and makes it difficult to draw definite conclusions in some cases; but for reasons mentioned by Mr. Relf it seems that *with proper caution* the indications are unlikely to be seriously misleading. We know of few cases in which an increase in Reynolds number makes a really turbulent flow smooth, so that a flow which appears to be turbulent (*e.g.*, round a shape with a very high resistance or a thoroughly stalled wing) is unlikely to become smooth at higher speeds. If some alteration in the shape is found to produce a great improvement in the smoke tunnel, it should at least be worth trying at higher Reynolds numbers. The method is not put forward as a complete one but it is a useful auxiliary. Moreover, not its least valuable feature is that it leads a keen observer to a far clearer realisation of what fluid flow is like than any other device known to the author.

ABSTRACTS AND NOTICES

FROM THE

SCIENTIFIC AND TECHNICAL PRESS

PHYSICS AND ENGINEERING SCIENCE

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(*Prepared by R.T.P.*)

No. 23. APRIL, 1932

Aircraft Design

Statistical Presentation of Flying Performances. (H. B. Helmbold, Z.F.M., Vol. 22, No. 21, 14/11/31, pp. 629-636.) (5.1/23451 Germany.)

The author introduces quantities of the dimensions of velocity and horse-power, expressed as functions of the weight, span, density and effective surface of resistance. On dividing the variables of velocity and power by these quantities, non-dimensional variables are obtained in terms of which the relation between velocity and power is readily expressed. Another non-dimensional quantity is the ratio of density at a given height from the density at sea level as a function of height from the international standard atmosphere. A large number of relations between pairs of non-dimensional variables are plotted graphically from tests on different types of machines for comparison, and the results are closely grouped on corresponding rectilinear loci. The numerical values of the non-dimensional variables are worked out for the Junkers' aeroplane and Junkers' engine to first and second approximations. The method is intended to give a reliable basis of comparison for the qualities of different types of machines.

Recent Problems in Aircraft Structural Design. (S. Bergmann and H. Reissner, Z.F.M., Vol. 23, No. 1, 14/1/32, pp. 6-12.) (5.15/23452 Germany.)

The paper is marked " Report No. 1 " and deals with buckling of thin plates supported at the boundary. The writer starts with Southwell and Skan's solution for isotropic plates (Proc.Roy.Soc. A.105, 1924) and the extension of the results by the authors and other writers to anisotropic plates.

The present paper carries the approximation further and has Southwell's solution as a lower limit. The formation and solution of the differential equation do not lend themselves to abstracting in detail. The method consists essentially

in finding the smallest particular value of a partial differential equation of the fourth order with two independent variables proportional to the Cartesian co-ordinates. The solution is expressed in trigonometrical series and completed by the determination of the coefficients.

The types of buckling are shown graphically by contour lines resembling those of Southwell's paper but considerably deformed.

Thirty-three references are given.

Graphical Solution of Beam Problems. (M. Watter, Aero Digest, Vol. 20, No. 3, March, 1932, pp. 33-35.) (5.25/23453 U.S.A.)

A graphical method of applying Berry functions to the solution of beam problems is outlined, and a worked out example is given.

Stress Calculations in Redundant Wing Structures. (A. E. Russell, Flight, Vol. 24, No. 13, 25/3/32, pp. 260a-260e.) (5.25/23454 Great Britain.)

A numerical example is worked out by a method of least work where a redundant wire is cut and increased stresses are imposed on the structure.

Meopham Aeroplane Crash, Junkers F.13, German Investigation. (267th D.V.L. Report, H. Blenk, H. Hertel and K. Thalan, Z.F.M., Vol. 23, No. 3, 15/2/32, pp. 73-86.) (5.152/23455 Germany.)

A comprehensive investigation was made at the D.V.L. on the possible causes and probable initial point of failure. The English experience, chiefly with biplanes, that if the wing fails first, the aeroplane reaches the ground with undamaged tail structure, is held not to apply to monoplanes of the Junkers type, in which subsequent rupture of the wing during fall is considered probable. A number of resonance effects were investigated and statical and dynamical limits of strength were determined. Full scale tests were carried out using a stream of smoke as an indicator of the motion of the air, and photographs show steady and turbulent types of flow under different conditions. Indicators were mounted on parts of the structure and records of vibrations were obtained. The results are given in thirty-three paragraphs.

Without excluding the possibility of the English explanation its probability is considered small in view of the German investigations. The suggestion appears to be that in bad weather without instruments for blind flying a steep dive through a cloud followed by a sharp pull-up, possibly accentuated by a gust of wind, may have produced an unusual accumulation of stresses sufficient to rupture the wing.

It is remarked that over a hundred aeroplanes of this type have been flying for years without an accident of this type.

Development of an Aeroplane Free from Auto-Rotation in Steep Landing. (W. Schmidt, Z.F.M., Vol. 22, No. 18, 28/9/31, pp. 546-549, and No. 19, 14/10/31, pp. 569-578.) (5.202/23456 Germany.)

Auto-rotation, the effective cause of spin, is due to the sharp peak in the lift curve or more rigorously in the normal component curve near stalling, which gives two values of the incidence and drag for one value of the normal force through the range covered by the peak.

The suggestion is made that a wing profile should be selected in which the peak disappears or becomes negligibly small. Four types of profile are considered and the peak of the normal component coefficient is seen to disappear or become negligible with Gottingen symmetrical profiles number 429 and 537.

A wing was constructed with a variable section showing a high lift profile at the base and tapering to a thin symmetrical profile at the tip. The coefficients of lift, drag and moment about the leading edge are shown graphically

against incidence and in a polar diagram. Distribution of lift along the span is also given and owing to the concentration near the centre heavy eddies must be given off along the trailing edge. Apparently this model was dropped.

Comparison is made of the lift curves of a free plate with 4-1 aspect ratio and Gottingen profile 537, 5-1 aspect ratio, the lift curves against incidence being very nearly identical.

As a further development the symmetrical profile is cut parallel to the spar in seven places and the partial sections are extended so as to give doubled effective chord, with seven slots at right angles to the surface. The lift incidence curve of a similar arrangement is given in Fig. 14. Experiments on a Handley Page slotted wing suggest that the lift will continue rising up to 90° incidence. On applying the principle to the wing tips only, the lift maximum is reached at increased incidence but then collapses suddenly, which gives the conditions for auto-rotation.

A further type of wing was examined in the wind channel with wing tips only spread out in a grid as described above. An end plate was inserted between the wing proper and the grid extension. In this form the normal reaction is rising up to 90° and no auto-rotation could be imposed.

Another wing with the grid extending over about one-third of the span from the wing tips was tested. Unexpectedly auto-rotation set in with this wing.

The article concludes with a summary of the analysis of auto-rotation, the numerical results being exhibited graphically.

Undercarriages, Floats and Hulls

Wave Resistance and its Practical Application. (G. Weinblum, Z.V.D.I., Vol. 75, No. 6, 6/2/32, pp. 127-131.) (5.51/23457 Germany.)

Michell's expression for wave resistance is quoted and the physical assumptions on which it is based are recapitulated. A non-dimensional resistance coefficient is defined and its values, plotted against a non-dimensional velocity coefficient, show marked oscillations. Observed values plotted on the same scale for comparison show much less marked oscillations. The centre of pressure and distribution of pressure on a hydroplane surface are also discussed.

Fifteen references are given.

Flow about Ship Models. (W. P. Roop, J. Franklin Inst., Vol. 213, No. 2, Feb., 1913, pp. 195-209.) (5.51/23458 U.S.A.)

A comparison is made of measured resistances as determined by Reynolds, Froude, Prandtl and others with special attention to the transition from linear to turbulent flow. The experimental results are plotted in the manner first applied at the Gottingen Aerodynamical Laboratory (Vol. 3, 1927).

Model Towing Tests on Seaplane Floats. (P. Schröder, Werft-Reederei-Hafen, Vol. 11, No. 16, 22/8/30, pp. 349-356.) (5.51/23459 Germany.)

The lay-out of the experiment is described and the difficulties of obtaining determinate conditions are admitted in the course of subsequent discussion.

Fig. 1 shows a tabular diagram of the arrangement of the forty individual tests applied. Resistance is shown as a function of speed for six different loadings. The influence of the wings and structure on the starting performance is discussed from the point of view of separation of the various quantities involved.

In Fig. 2 the moment is plotted against speed for incidences of 1°, 3°, 5°, 7° and 9°.

In Fig. 4 resistance is plotted against lift for eighteen different speeds at trim angle of 1°.

The methods are applied to the design of a projected trans-Oceanic Rumpler seaplane by scaling up in the ratio of 16 to 1. The results predicted for the full size machine are shown graphically and include the lift of the floats, the resistance and the moments at incidences of 1°, 3°, 5° and 7°. These are applied to the prediction of the starting performance, in which all the quantities are plotted against speed for two positions of the c.g.

Stresses on Floats and Hulls during Starting and Alighting. (R. Verduzio, L'Aerotecnica, Vol. 11, No. 11, Nov., 1931, pp. 1343-1405.) (5.56/23460 Italy.)

The author gives a compact summary of work on shocks on seaplane floats and hulls during starting and alighting, carried out in Great Britain, Germany, U.S.A., etc.

Eighteen references are given.

Reduced Effective Mass of an Aircraft Landing on One Wheel. (J. Taub, Z.F.M., Vol. 23, No. 1, 14/1/32, pp. 23-24, 265th D.V.L. Report.) (5.55/23461 Germany.)

In accordance with elementary rigid dynamics impact on one of a pair of wheels, not applied at the effective centre of percussion, is reduced by a factor depending on the maximum value of the radius and product of gyration of the whole machine with respect to the line of impact reaction. Mean values of this factor are tabulated for different distributions of mass. With highly centralised masses the minimum calculated figure is 0.20, while the minimum experimental value is 0.39. The nature of the stresses produced is not discussed.

Airscrews

Vibration of Elastic Beams with Application to Airscrew. (K. Hohenemeser, Z.F.M., Vol. 23, No. 2, 28/1/32.) (5.65/23462 Germany.)

The equations are formed for the natural period of a cantilever elastic beam for the fundamental mode and the overtones. Deflections are shown graphically for the first and second overtones. An example is worked out for an airscrew blade and the numerical results are tabulated for the principal mode and for the first and second overtones. It is shown that the latter may arise with engines of more than five cylinders.

Mutual Influence of Engine and Airscrew Characteristics. (J. D. Blyth, Flight, Vol. 24, No. 9, pp. 174a-174d.) (5.65/23463 Great Britain.)

The relations between engine performance and airscrew characteristics are worked out numerically for the use of designers.

Variable Pitch Airscrew, Marchetti. (L'Aerophile, No. 12, 15/12/31, p. 371.) (5.658/23464 France.)

The airscrew is constructed of duralumin, absorbs 550 h.p. at 2,000 r.p.m. and weighs 80 kg. complete. Diameter 3 m. Pitch variable from 1.5 m. to 2.5 m.

It is stated that the range of the Marchetti aeroplane, holder of the long distance record, was increased 15 per cent. by the use of this airscrew.

Controllable and Automatic Airscrews. (D. A. Dickey and O. R. Cook, S.A.E. Jrnl., Vol. 30, No. 3, March, 1932, pp. 105-111.) (5.658/23465 U.S.A.)

A comprehensive technical account is given, illustrated by 10 photographs of five hubs, one made by the Army Air Corps, the others by private firms.

Adjustable pitch airscrews which can only be set on the ground with a stationary engine are fairly general. The greatest difficulty is the design of an

airscrew within the limitations of weight and space. The automatic airscrew is the only one to be considered for fighting aircraft, and shows least progress. Controllable airscrews with two or at most three pitch positions, controlled by the pilot in flight, offer a reasonable compromise.

A satisfactory design has not yet been produced.

Variable Pitch Airscrew. (G. Leparmentier, Vol. 2, p. 94, Reports of First International Congress de la Sécurité Aérienne.) (5.658/23466 France.)

A description is given with four photographs and a sketch of an airscrew with automatic variable pitch. The pitch is determined by the balance of centrifugal and aerodynamical forces and shaft torque. At no torque the airscrew may act as a brake.

Automatic Variable Pitch Airscrew. (H. C. H. Townend, J.R. Aer. Soc., Vol. 36, No. 254, Feb., 1932, pp. 111-126.) (5.658/23467 Great Britain.)

A description is given with a photograph and diagram of an automatic variable pitch airscrew designed on the same principle as the Leparmentier airscrew (see foregoing abstract). The relations between torque, aerodynamic forces, and incidence are discussed analytically and plotted graphically. It is possible to arrange the guides so that in case of engine failure the blades assume the position of minimum head resistance.

Instruments

Manometry of Explosions. Comparative Performance of Some Diaphragm Type Explosion Manometers. (Fuel, Vol. 11, No. 3, March, 1932, p. 118, U.S. Bureau of Mines Technical Paper 496 (1931).) (6.251/23468 Great Britain.)

Five manometers were compared, using H_2/air mixtures. The records of the instruments show fair agreement during the pressure rise but diverge at the maxima and in the subsequent cooling curves.

Mechanical defects are discussed in detail.

Aircraft Vibration. (H. Constant, J.R. Aer. Soc., Vol. 36, No. 255, March, 1932, pp. 205-250.) (6.48/23469 Great Britain.)

A description is given of the Cambridge vibrograph, with an example of the diagrams traced and a brief discussion of the principles of analysing them. The physiological effects are briefly considered. A large number of numerical cases is exhibited graphically of the periodic forces imposed by engines and airscrews and various aerodynamic effects and the resulting vibrations set up. The discussion brought out sufficiently the considerable difficulties of measurement and interpretation.

The paper is the most substantial quantitative contribution to the subject yet published and will no doubt be esteemed as such in the design room.

A Recording Theodolite. (R. H. Ward, Army Ord., Vol. 12, No. 70, Jan.-Feb., 1932, pp. 272-275.) (9.61/23470 U.S.A.)

A descriptive technical account is given of a theodolite combined with a film camera, illustrated by a diagram of the optical system and two photographs of the apparatus. The elementary trigonometry of the problem is exhibited graphically. One theodolite is placed at each end of a measured base. When the film records both the position of the target and of the shell burst the magnitude of the error can be readily reduced. The apparatus appears to be suitable for reducing results after firing practice and as such would have value in training A.A.C. gunners, but would not be applicable to fire control under service conditions.

Stability and Control

Stability and Controllability. (J. Biche, Rev. Soc. Aeron., No. 1, Jan., 1932, pp. 12-19.) (7.2/23471 France.)

The equations of longitudinal and lateral stability are applied to considerations of design of controls.

Tail-less Aeroplanes. (M. Schrenk, Z.V.D.I., Vol. 76, No. 3, 16/1/32, pp. 63-66.) (7.25/23472 Germany.)

A brief summary is given of the stability, controllability, moments of inertia and other properties of tail-less aircraft. Two photographs of a German type, with engine and airscrews and some graphical stability characteristics are reproduced. The advantages incidental to this type of construction are not underestimated, and a favourable view of its future is taken. Fifteen references are given.

Safety in Spinning. (H. B. Irving and A. V. Stephens, J.R. Aer. Soc., Vol. 36, No. 255, March, 1932, pp. 145-204.) (7.62/23473 Great Britain.)

A previous paper by Gates and Bryant, R. & M. 1001, summed up comprehensively progress in the investigation of spinning to the date of publication. The present paper gives an equally comprehensive survey of subsequent progress, principally in obtaining numerical values for the aeroplane characteristics which come into the problem, and applying them to determine rules of design for minimising the danger of spin. To summarise the paper it would be necessary to refer to almost every aerodynamical and dynamical characteristic of the aeroplane. A comparatively small number of these characteristics, however, are shown to have the principal effect in determining spin characteristics, and practical rules are laid down for the guidance of designers.

Control Beyond the Stall. (G. Lachmann, J.R. Aer. Soc., Vol. 36, No. 256, April, 1932, pp. 276-338. Paper read before Roy. Aer. Soc., 17/12/31.) (7.72/23474 Great Britain.)

Much interesting material is given from the history of the development of the slot as a means of preventing stall. Recent developments are fully discussed. Munk's statement is quoted that 90 per cent. of known wing profiles are incapable of being rendered stable by wing slots, a restriction which designers do not apply with sufficient care. The fitting of slots is most effective with wings of rectangular plan at the tips. Rounded tips are unstable. At times it is desirable to disturb the smooth flow of the wing tip prematurely. This may be done by closing the slot or by operation of a hinged plate at right angles to the flow. The closing of the slot may be automatic. Alternatively the slot or the " spoiler " plate may be connected to the aileron. Diagrams show the mechanism applied. The nature of the flow behind the wing is a more highly complicated matter and receives correspondingly elaborate treatment. The principle of setting the tail wing high to avoid interference may be effective in normal flight but in stalled flight the author considers that the contrary is the case and that the disturbed region at stalling incidence will affect a high set tail unit more heavily than a low set unit.

The technique of stalled landings is discussed at length.

The paper may be regarded as a comprehensive report of developments of control and stability in sequel to R. & M. 1000.

Fog, Flying and Landing

Flying and Landing in Fog, a Radio System. (H. Diamond and F. W. Dunsmore, Aeron. Eng., Vol. 4, No. 1, March, 1932, pp. 13-20.) (7.8/23475 U.S.A.)

A descriptive account is given of the application of a system of radio beacons developed by the Bureau of Standards (see previous abstracts Nos. 17/20361 and 19/21325, etc.). Seven photographs of the apparatus are given and seven diagrams of installation and connections. A sketch shows the complete installation in an aeroplane.

Engine Design

Thermodynamics

Combustion Process in I.C. Engines, Electrical Method of Investigation. (K. Schnauffer, Z.F.M., Vol. 22, No. 17, 14/9/31, pp. 526-530.) (8.13/23476 Germany.)

The flame travelling through the cylinder is associated with changes in the ionisation of the gas, which factor can be recorded electrically. Knocking is due to a very rapid completion of the combustion which has been originated by a relatively slow flame travel. It appears that different types of knocking arise from pre-ignition, excessive turbulence, and over-heating.

A number of photographs are reproduced.

Photographic Investigation of Flame Movements in Gaseous Explosions. (W. A. Bone and R. P. Fraser, Phil. Trans. of Royal Society, Vol. 230, No. A.690, 16/12/31, pp. 363-385.) (8.13/23477 Great Britain.)

Detonation is distinguished from the initial phase of an explosion not merely by much faster propagation of ignition but also by a more intense combustion on the flame front. During the initial uniform movement a relatively small portion of the explosive mixture is burnt in the flame front itself, and the reaction may be completed by shock waves.

Experiments were carried out in open tubes mostly on CO mixture, and a series of beautiful photographs is shown.

Process of Combustion with Spark Ignition. (K. Schnauffer, Z.V.D.I., Vol. 76, No. 3, 16/1/32, p. 69.) (8.13/23478 Germany.)

Photographic records of the process of combustion of spark ignition are discussed in a short note. Two flame photographs and accompanying pressure diagrams are reproduced and their interpretation is discussed. Five references are given.

Combustion in a High Speed C.I. Engine. (A. M. Rothrock, N.A.C.A. Report, No. 401, Jan., 1932.) (8.25/23479 U.S.A.)

Combustion should begin before the injection ends. The tendency to detonate decreases as the compression ratio is raised. Supercharging the engine much improves combustion by the combined effect of increase of density and temperature of the inlet air in decreasing the ignition delay. Twenty-seven recent references are given.

Effect of Orifice Length-Diameter Ratio on Fuel Sprays for C.I. Engines. (A. G. Gelalles, N.A.C.A. Report, No. 402, Jan., 1932.) (8.25/23480 U.S.A.)

High speed cinematographs were made of individual fuel sprays from various nozzles, the discharge taking place into air at room temperature and at various pressures.

The results were modified by helical grooves on the stem of the injection valve.

Generally speaking, best penetration and highest coefficient of discharge were obtained for a length-diameter ratio varying between 4 and 7.

Supercharging

Supercharging. (R. J. Nebesar, Aer. Eng., Vol. 4, No. 1, pp. 1264a-1264e. Paper read before A.S.M.E.) (8.235/23481 U.S.A.)

The elementary relations between power and flying of supercharged engines are discussed with reference to change of altitude and density. Supercharged power against altitude curves are given for the Wright Whirlwind Jupiter and Packhard Diesel engines. The effect of increasing the linear dimensions of the aircraft is also considered.

The Design of Turbo-Blowers. (R. Müller, Z.V.D.I., Vol. 75, No. 22, 30/5/31, pp. 689-695.) (8.25/23482 Germany.)

A semi-empirical expression is constructed for the flow of gas through the various stages of a turbo-blower taking into account friction, leakage, and internal or external cooling. The calculated configuration of flow through the blading is compared with observations, with reference to instability and losses.

The Effect of Increased Carburettor Pressure on Engine Performance at Several Compression Ratios. (O. W. Schey and V. G. Rollin, N.A.C.A. Report, No. 404.) (8.275/23483 U.S.A.)

The boost pressures ranged up to 5lbs. per sq. in., the compression ratio varying between 3.5 and 7.5 The increase in B.M.E.P. was of the order of 40 per cent. At any one compression ratio the effect of boost on fuel consumption on a net b.h.p. basis is negligible. Since the experiments were carried out on a single-cylinder 5 by 7 engine, a definite saving in specific fuel consumption can be expected on a multi-cylinder engine from improvement in distribution.

New Working Method for Carburettor Engines. (Z.V.D.I., Vol. 76, No. 2, 9/1/32, p. 46.) (8.281/23484 Germany.)

It is proposed to compress a very rich incombustible mixture and inject highly compressed air at the end of the stroke. Control is either by varying the amount of mixture or the amount of air injected.

Ignition is either by spark or by the heat of compression. High efficiency and freedom from detonation is claimed for this scheme.

Heavy Oil C.I. Engines

Development of Heavy Oil Engines for Cars and Aircraft. (W. Schwerdtfeger, Autom. Tech. Zeit., Vol. 34, No. 30, 31/10/31, pp. 677-679.) (8.25/23485 Germany.)

" Figure of merit " is defined as the product of the r.p.m. and the mean effective pressure divided by cylinder volume. Seventy-four engines are listed and the quantities referred to are tabulated. The results are also plotted graphically. Junkers 600 h.p. 1100 r.p.m. 2-stroke cycle engine shows the highest figure. As might be expected the figure for engines with a 2-stroke cycle is about double that of engines with a 4-stroke cycle.

Two New Maybach C.I. Engines. (A. E. Thiemann, Autom. Tech. Zeit., Vol. 34, No. 29, 20/10/31, pp. 659-660.) (8.25/23486 Germany.)

The main dimensions and characteristics are given of 150 h.p. and 410 h.p. types with side and end elevation sketches and photographs of the crankcase,

crankshaft and piston. A diagram of performance is also given showing a minimum consumption of slightly under 180 gr. of fuel per h.p. hour for 100 h.p. and 270 h.p. respectively, at 800 r.p.m. in both cases.

High-Speed Diesel Engine. (Z.V.D.I., Vol. 76, No. 10, 5/3/32, pp. 233-234.) (8.25/23487 Germany.)

The commercial 6-cylinder engine develops 375 h.p. at 900 r.p.m. The B.M.E.P. is 75lbs. per sq. in., consumption .36lbs. per b.h.p. hour, weight approximately 15lbs. per h.p.

With a supercharger the power is increased to 500 h.p. without change of specific fuel consumption. The use of aluminium, steel and cast iron in the construction is of interest. Several parts are fitted with needle bearings.

The Compression Stroke of the Pre-Combustion Chamber Oil Ignition Engine. (K. Schlaefke, Z.V.D.I., Vol. 75, No. 33, 15/8/31, pp. 1043-1046.) (8.38/23488 Germany.)

The author attempts an analysis of the pressure and temperature in the cylinder and ignition chamber.

The results are presented in a graphical form and expressions are obtained for different crank angles. Eleven references are given.

The Pratt and Whitney Petrol Injection Engine. (L'Aeron., No. 153, Feb., 1932, pp. 59-61.) (8.292/23489 France.)

The experimental engine follows the general lines of the Hornet. Spark ignition is retained but the carburettor has been replaced by nine injection jerk pumps. Governed by altering the stroke. The suction stroke of the pump is gradual, the injection stroke very rapid, the plunger being returned against a variable stop by a very strong spring.

The injection pumps are fed by a separate fuel circulating pump, special care being taken to prevent the entry of gas bubbles into the injection system.

Crankshaft Torsion

Vibrating Dampers for Crankshafts. (O. Föppl, Z.V.D.I., Vol. 75, No. 32, 8/8/31, pp. 1028-1029.) (8.36/23490 Germany.)

It is found that an elastic coupling with appropriate torsional characteristics increases the damping effect and permits a reduction in the size of the damper.

Crankshaft Failures in Civil Aviation. (E. Everling, Autom. Tech. Zeit., Vol. 35, No. 1, 10/1/32, pp. 22-23.) (8.36/23491 Germany.)

The D.V.L. has collected specimens of crankshaft fractures which have taken place during recent years in six-cylinder engines. The fractures generally occur near the airscrew end and are spiral. They are due to resonance, which is effectively eliminated by a suitable damper.

In no case was failure due to faulty material. In forging the shaft care should be taken that the grain of the steel follows the crank throw.

Practical Investigation of Torsional Oscillations. (K. Lürenbaum, Z.F.M., Vol. 23, No. 4, 29/2/32, pp. 105-113, 268th D.V.L. Report.) (8.36/23492 Germany.)

A description is given of the D.V.L. recording torsion meter, and specimens of the time and duration records are reproduced. The records are made by scratching on a glass plate. The elastic properties and internal damping of the rubber coupling are exhibited graphically. Several records are reproduced on an enlarged scale. The airscrews are connected to the engine by a long shaft

denoted as a "distant drive," the properties of which are investigated, and the results are shown graphically for different conditions.

Records of two radial engines are shown, one of a 9-cylinder radial of a natural period of 3,400, the other a 5-cylinder radial with a natural period of 10,600. A table gives numerical results of 13 tests on six engines under different conditions, and gives the fudamental period, the ratio of the first critical speed to the fundamental, the maximum amplitude at the free end of the shaft, the maximum resulting stress, the ratio of the latter to the mean stress, maximum calculated resonance torsion, and remarks on the nature of the damage, if any. Damping is discussed and a satisfactory characteristic is shown for a Junkers L88 engine with internal damping.

Influence of Method of Fuel Supply on Torsional Oscillations. Relation between Order of Firing a Nine-Cylinder Engine and Torsional Oscillations. (K. Schlaefke, Autom. Tech. Zeit., Vol. 34, No. 33, 30/11/31, and No. 34/35, 15/12/31.) (8.36/23493 Germany.)

Pp. 759-780. A comparison between carburettor engines and direct injection engines is made by means of graphical representation of indicated pressure and direct variation. The harmonics are shown graphically and show that the direct injection engine suffers more from torsional resonance on the fifth harmonic. Below the corresponding speed there is not serious difference between the two types of engine.

Pp. 781-783. The natural periods are determined and exhibited graphically for the first and second natural periods. The mean indicated pressure and the torque are shown as functions of the r.p.m. The harmonics are plotted for six different orders of firing, the amplitudes of the fourth and eighth harmonics being independent of the order, the fifth, sixth and seventh harmonics showing wide variations in the amplitudes according to the order of firing, but in no case equalling the amplitude of the eighth harmonic, which in turn is only 60 per cent. of that of the fourth harmonic.

Forces on Crank Pins. (Karl Herr, Autom. Tech. Zeit., Vol. 34, 1931, Nos. 27, 28, 30, 33, 34, 35 and 36.) (8.36/23494 Germany.)

An exhaustive study is given of the variation of the forces on the crankpin round a complete cycle of two strokes. The elementary formulæ are developed. Ten force-vector diagrams are drawn, two for each cycle of four strokes. The components along the crank and along the connecting rod are shown for 24 angular positions. From these subsidiary diagrams are derived showing the variation of the pressure on the crankpin, etc., both in polar form and in cartesian co-ordinates. Numerical calculations are carried out in conjunction with the diagrams.

Piston Rings

Piston Ring Mounting. (L'Aeron., No. 152, Jan., 1932, p. 18. French Patent No. 685506. P. Clerget.) (8.38/23495 France.)

The piston has detachable lands fixed in position by steel wedges, so that the ring need not be opened out when fitting to the piston.

Cooling

Interchange of Heat between Pipe and Water. (W. Nusselt, Forschung, Vol. 2, No. 9, Sept., 1931, pp. 309-313.) (8.4/23496 Germany.)

The experimental arrangements of Th.Burbach (1930) and of Eagle and Ferguson (Proc. Roy. Soc., London, Vol. 127, No. 540, 1930) are shown in diagrams. A form is assumed for the relation sought as a product of indeter-

minate powers of non-dimensional quantities. The experimental results are tabulated and plotted and numerical values are introduced for the indeterminate indices and for a multiplying constant. Similar treatment is applied to the experiments of Eagle and Ferguson.

The author considers that a good fit has been obtained in both cases with his empirical formula. Three references are given.

Transference of Heat from a Hot Tube to Water. (G. Ackermann, Forschung, Vol. 3, No. 1, Jan.-Feb., 1932, pp. 42-50.) (8.4/23497 Germany.)

Experiments were carried out with a horizontal tube at rest in still water, and the cooling is due principally to convection currents. The physical discussion follows briefly the same lines as Nusselt (see foregoing abstract). The experimental apparatus is described and illustrated and the numerical observations are tabulated and shown graphically. Comparison with Nusselt's formula shows close agreement over a considerable range of temperatures.

New American Investigation of Heat Transference and Laminar Flow. (H. Kraussold, Forschung, Vol. 3, No. 1, Jan.-Feb., 1932, pp. 21-24.) 8.4/23498 Germany.)

Péclét introduced the non-dimensional quantity vl/K (v=velocity, l=linear dimension, K=thermometric conductivity) in a discussion on convection currents. This is analogous to Reynolds number vl/ν in the equations of viscous fluid motion. In the present paper the empirical expression due Léveque is quoted, in which Péclét's number and the ratio of diameter to standard length of pipe appear as non-dimensional parameters. The American results are plotted graphically on logarithmic scales showing the quantity of heat transferred as a function of Péclét's number in comparison with the values calculated from Léveque's formula and for a more elaborate formula due to the author. Léveque's formula involves the product of the $\frac{2}{3}$ power of the parameters, while the author's formula involves empirical indices expressed to the 4th and 5th significant figures. The experimental points are grouped along a straight line, but do not agree closely with the empirical formulæ. Eleven references are given.

High Temperature Liquid-Cooled Aircraft. (A. Nutt, Aero. Digest, Vol. 20, No. 3, Mar., 1932, p. 36.) (8.44/23499 U.S.A.)

It is stated that a saving of 0.2lbs. per h.p. in weight and 35 per cent. area in the radiator are obtained by using ethylene glycol as cooling medium. Graphical representations of performance show minimum consumption at about 140°C. radiator temperature. Absolute ethylene glycol has b.p. of 197°C. which falls to 160°C. with 4 per cent. water content and 144°C. with 10 per cent. water.

Lubrication

Wing Radiator Development. (G. A. Luburg, Aeron. Eng., Vol. 4, No. 1, March, 1932, pp. 37-40.) (8.444/23500 U.S.A.)

A brief technical description is given of types of tube and comparative heat dissipation of six types of radiator is shown graphically. The dimensions, weight, cooling area, weight of water, horse-power, etc., are given for eleven high-speed aeroplanes. Five references are given.

Lubricating Oil at Low Temperature. (S. Erk, Z.V.D.I., Vol. 76, No. 2, 9/1/32, pp. 33-36.) (8.54/23501 Germany.)

Physical characteristics of oils at low temperatures such as the " pour-point " are compared amongst themselves and with absolute viscosity determinations. Similar factors influence lubricating quality or " oiliness " and the point of coagu-

lation, and the latter appears to be a useful criterion for lubricating quality at much higher temperatures.

Phenomena of Lubrication in Bearings. (W. Nücker, Forschungsheft, 352, Jan.-Feb., 1932.) (8.54/23502 Germany.)

A description is given of the elaborate experimental installation with photographs and diagrams showing the general arrangement of the details of the apparatus for measuring temperature, pressure, thickness of film, position of shaft, axis of bearing, etc. The very extensive experimental data obtained are plotted in a series of diagrams. The theoretical work of Reynolds and Michell, elaborated by numerous subsequent writers, is discussed, and calculated and experimental values are compared, and generally speaking, agree with a high degree of accuracy. Fifty-two references are given.

Fuels

Low Temperature Tars. (G. T. Morgan, J. Soc. Chem. Ind., Vol. 51, No. 9, 26/2/32, pp. 67-80T.) (8.6/23503 Great Britain.)

A comprehensive survey is given of the method of analysing low-temperature tars developed at the Chemical Research Laboratory, Teddington. Distillation up to 120° at atmospheric pressure removes water and light oils. Successive extractions with aqueous alkalis and dilute mineral acids separates the major fractions, phenols, bases, and neutral oils. A second distillation up to 120° under 2 mm. air pressure separates the second light oil fraction. Of the imposing range of substances separated only fuels for internal combustion engines need be mentioned here. The annual reports of the Fuel Research Station state that one ton of coal may furnish 15 gallons of motor spirit, b.p. 230-60°.

The use of phenols as auto-detonants is also discussed.

Compression Ignition Characteristics of Ignition-Engine Fuels. (A. W. Pope and J. A. Murdock, S.A.E. Jrnl., Vol. 30, No. 3, March, 1932, pp. 136-142.) (8.64/23504 U.S.A.)

The fuel is tested under motoring conditions in a variable compression engine running at 600 r.p.m. with pre-heated air. The critical compression ratio at which auto-ignition just takes place is taken as the grading characteristic. The lower the value the better the fuel for compression ignition. A good Diesel fuel auto-ignited at CR.8, while high grade petrol required CR.14.

Ethyl lead scarcely affected compression ratio for auto-ignition, but a benzol blend giving equivalent octane number increased the critical compression ratio.

Rationalisation of Fuel Consumption. (A. E. G. Report, Autom. Tech. Zeit., Vol. 34, No. 36, 31/12/31, pp. 803-807.) (8.64/23505 Germany.)

The exhaust gases were analysed and the proportions of CO_2, CO, H_2, $CH_4+C_2H_6$ are shown graphically. The ratio CO/CO_2 is shown as a measure of poisonous quality. The carburettor spray was examined and photographs show the size and distribution of the drops. A description of the research apparatus is given with photographs and diagrams.

Total Heats and Specific Heats of Synthetic Paraffinic Distillates and Some Petroleum Fractions. (A. J. E. Swann, Fuel, Vol. 11, No. 3, March, 1932, pp. 113-118.) (8.64/23506 Great Britain.)

The specific heat shows a linear increase with temperature from 0°C. to 100°C. The total heat curve is consequently parabolic, and this relation holds from 0°C. to 150°C.

Investigation of the Knocking of Carburettor Engines. (L. Auer, Z.V.D.I., Vol. 75, No. 22, 30/5/31, pp. 679-680.) (8.645/23507 Germany.)

A modification of the Midgley bouncing pin is described. Both intensity and the time of the knock are recorded, not only at the cylinder wall, but also at the piston crown. It appears that the knock depends on the rate of flame propagation. If the latter exceeds a certain amount the ignition is propagated by an explosion wave.

Fuel Injection System. (A. V. D. Willgoos, U.S. Air Services, Vol. 17, No. 2, Feb., 1932, pp. 35-36.) (8.68/23508 U.S.A.)

A brief technical description with a photograph is given of the fuel injection system tested in flight on a Pratt and Whitney Hornet engine. The system is still in an experimental stage.

Carburettor. (Solex Co., Patent No. 685699, L'Aeron., No. 153, Feb., 1932, p. 48.) (8.701/23509 France.)

A restriction between the inner tube and the surrounding sheath gives a more gradual emptying of the fuel in the well and improves acceleration.

Jerk Pump Injection for C.I. Engines. (S. W. Nixon, Autom. Eng., Vol. 22, No. 289, Jan., 1932, pp. 31-36.) (8.705/23510 Great Britain.)

The action of the jerk pump and differential needle atomiser is described in principle and illustrated by diagrams. Methods of control include variable stroke, variable valve opening, variable by-pass, and variable delivery on the suction side. Control of the rate of injection through the stroke is considered essential for successful operation. Eight pressure diagrams are reproduced showing the variation of pressure during the injection period with various types of control. It is necessary to maintain constant or preferably slightly decreasing delivery of the pump at constant control position with rising speed. A diagram shows the latter condition (slightly decreasing delivery) with two types of valve. Another diagram shows irregular control produced by poor spilling arrangements for decreasing delivery.

The action of the differential needle atomiser in atomising the solid stream by rapid vibrations is considered with reference to practical operation, and possible developments are considered.

An outline of test methods is given and typical record of delivery against hours run is reproduced. Elasticity of the fuel is an essential datum. Four numerical examples are worked out.

W.V. Piston Fuel Pump. (Autom. Tech. Zeit., Vol. 34, No. 15, 31/5/31, p. 364.) (8.741/23511 Germany.)

A section drawing is given of the W.V. piston fuel pump, with a curve of pressure and delivery plotted against r.p.m.

Transmission Gears

Elastic Coupling for Shafts. (Z.V.D.I., Vol. 76, No. 35, 29/8/31, p. 1109.) (8.75/23512 Germany.)

The coupling resembles an eccentric vane blower, the blades of which engage with slots in the casing. The drive is between the "rotor" and the "casing," the vanes being in the form of steel springs which traverse the "rotor."

Reduction Gear. (Argus Co., D.R.P. 507871, L'Aeron., No. 153, Feb., 1932, p. 51.) (8.765/23513 Germany.)

Some of the intermediate gear wheels in a planetary reduction gear are mounted on elastic shafts to maintain equal tooth loading.

Armament

Pivoting of Guns. (Methling, Z.V.D.I., Vol. 75, No. 20, 16/5/31, pp. 623-629.) (9.11/23514 Germany.)

The article deals mainly with ship mountings, but some reference is made to the mounting on lorries of anti-aircraft guns. There are 29 illustrations.

Materials

Materials of Aircraft Construction. (P. Brenner, Z.F.M., Vol. 22, No. 21, 14/11/31, pp. 637/648, 258th D.V.L. Report.) (10.1/23515 Germany.)

Wood construction. The properties of wood are considered under the headings of strength, joints and effects of humidity. The diagrams of tensile and compressive strength exhibit groups of test results for pine and spruce. The advantages of plywood are exhibited in a diagram which shows a steady falling off of the tensile strength of plain timber as the direction of application of stress varies from 0° to 90° inclination with the fibres, while properly designed plywood retains a fairly constant mean strength over the whole range. Mean test values of the strength of seven timbers in compression, tension, bending and torsion are tabulated. Splice joints, plates and clamps are considered briefly.

The relations of tensile strength and elastic modulus to moisture content are exhibited graphically.

Metal construction. The buckling strengths of various metals in use are given graphically and tabulated sketches of built-up metal wing spars are given in comparison with a built-up wooden spar. Fatigue tests are discussed and test values are plotted up to 100 million alternations.

Corrosion. The question of corrosion receives lengthy consideration, particularly with reference to riveted joints in seaplane construction, and photographs are reproduced showing the effects of corrosion of flying-boats' hulls in riveted duralumin plate. Comparative duration corrosion tests on magnalium and duralumin are given graphically and show a falling-off of tensile strength and extension of test pieces with exposure up to a hundred days.

Welding is considered briefly and microphotographs exhibit the change in grain structure of steel tube and of stainless steel plate.

The Physical Factors Determining the Path of Fatigue Fractures. (A. Thum and H. Oschatz, Z.V.D.I., Vol. 76, No. 6, 6/2/32, pp. 132-134.) (10.104/23516 Germany.)

A number of diagrams of the concentration of stress lines at sharp angles in stressed materials are reproduced. It is suggested that the fatigue follows the steepest gradient at right angles to the stress lines. In two photographs the direction of the line of fracture is held to support this view. Five references are given.

Corrosion

Corrosion Protection—Oxide Films. (Z.V.D.I., Vol. 75, No. 35, 29/8/31, p. 1110.) (10.125/23517 Germany.)

A small proportion of silicon in iron, and of antimony in aluminium, favours the formation of protective coatings under the action of air and water.

In the anodic oxidation of aluminium and the nitriding of suitable steels the protective layer is produced by reaction with chemicals.

A satisfactory theory of corrosion has not yet been established, and methods are empirical.

Welding

Autogenous Welding. (Z. Metallk., Vol. 24, No. 1, Jan., 1932, pp. 19-22.) (10.14/23518 Germany.)

The well-known incidence of corrosion round rivets is avoided by welded joints. Methods of welding in use are discussed and illustrated with five photographs of welds and a number of sketches. Eleven references are given.

Electron and Welding. (H. A. Horn and K. Tewes, Autom. Tech. Zeit., Vol. 34, No. 33, 30/11/31, pp. 762-765.) (10.28/23519 Germany.)

The authors state that welding of magnesium plates and castings is now practicable. Precautions to be taken in welding are stated and illustrated by sketches. A photograph shows a weld in detail from both sides, and six examples of welded objects are given. These vary from a fuel tank to a motor bus frame. Corrosion difficulties are briefly discussed and it is stated that the weld suffers less than the main body of the metal. The outstanding advantage of electron is the s.g. of 1.8 to 1.83, about two-thirds that of competing aluminium alloys. The chief weakness is liability to corrosion.

Alloys

Magnesium Alloys. (G. D. Welty, S.A.E. Jrnl., Vol. 30, No. 3, March, 1932, pp. 112-115.) (10.232/23520 U.S.A.)

The mechanical properties of aluminium and magnesium alloys for heat-treated castings and forgings are specified, and six photographs of castings in magnesium alloy are reproduced; practice in casting, forging, machining and treatment against corrosion are discussed. The quantity of magnesium castings used for aircraft in the U.S.A. has increased from 900lbs. in 1926 to 64,500lbs. in 1931.

Aluminium Alloys, Protection Against Corrosion. (R. W. Buzzard and W. H. Mutchler, N.A.C.A. Tech. Note, No. 400, Nov., 1931.) (10.262/23521 U.S.A.)

The whole question of protection of aluminium alloys against corrosion is surveyed in the light of experience at the Bureau of Standards. The indisputable superiority of alclad is re-stated but its higher initial cost and slightly decreased mechanical properties apparently suffice to restrict its use. The development of protective coatings for aluminium alloys therefore remains important. A complete specification is given of the various methods of applying coatings and of test methods by exposure to weather and corrosion.

Protective methods are divided into three broad classes :—

(*a*) Production of an oxide film on the surface of the material.

(*b*) Non-metallic coatings applied directly to the surface.

(*c*) Metallic coatings applied by electro-chemical or mechanical processes.

A number of these are effective in a temperate climate at a distance from the sea. Exposure to sea water is a much severer test, and the only effective type of protection appears to be the application of paint to an anodised surface. Under static test, corrosion in the last case was just beginning after three years' exposure, but it failed to penetrate the aluminium layer of alclad in the same period. Ten references are given.

Wind Tunnels and Testing Gear

Wind Tunnel Correction. (L. Poggi, L'Aerotecnica, Vol. 11, No. 4, April, 1931, pp. 424-445.) (11.16/23522 Italy.)

The effect of the walls of a wind tunnel on an eddy are discussed by the method of conformal transformation, and expressions are obtained in terms of

elementary functions and numerical values tabulated. The results are compared with Prandtl's simpler formula for a circular tunnel and also with the results of T. Osaki for a slightly different problem.

Acknowledgment is made to Prof. v. Karman, under whose direction the work was carried out.

Lift Coefficient of a Model, Effect of Walls on a Wind Tunnel. (T. Sasaki, Rept. Aer. Inst., Tokyo Imperial University, Nos. 46, Dec., 1928, and 77, Dec., 1931.) (11.16/23523 Japan.)

In sequel to the earlier paper the author extends his analysis to include the effects of exit and collector walls for channel wall interference in terms of sigma, zeta, theta, and Weierstrass functions. In a note the author accepts a correction (by Rosenhead) which removes a discrepancy between his results and Glauert's results by an approximate summation.

See previous abstracts (Rosenhead) Nos. 17/20336 and 20/22144.

X-Ray Test of Structures. (Aviation, Vol. 31, No. 2, Feb., 1932, p. 75.) (11.34/23524 U.S.A.)

It is stated that a portable X-ray apparatus mounted on casters is in use at a Curtiss-Wright airport for the rapid examination of the condition of the spars, etc., on a fluorescent screen. Where defects are indicated an X-ray photograph is taken.

Airships

World Travel of the Graf Zeppelin. (Luftwacht, No. 12, Dec., 1931, p. 532.) (12.1/23525 Germany.)

The airship has carried out 232 flights of 350,000 kilometres total distance in 3,500 hours.

A regular trans-Atlantic airship service in the near future between Europe and South America is projected with a 72 hours' run to Pernambuco. A new Zeppelin is under construction to be equipped with oil engines and filled with helium.

Comparison between Akron and Graf Zeppelin. (H. Ebner, Z.V.D.I., Vol. 76, No. 2, 9/1/32, p. 37-40.) (12.1/23526 Germany.)

The Akron has a capacity of 184,000 m.^{3} against the Zeppelin 105,000 m.^{3} the length of the two ships being practically identical (app. 238 m.). In many respects the constructional features of the Akron seem to follow those of the R.101 except that no steel is employed in the framework. It is interesting to note that the gas bags contain no gold-beater's skin, reliance being placed on rubber and wax. The ship is filled with helium. The eight Maybach petrol engines are inside the ship and exhaust water recovery plant is fitted. A maximum speed of 135 km./hr. was expected at 3,000ft. Apparently this was not achieved on the first trial flights. It is estimated that the ship has a cruising radius of 17,000km. and can remain in the air for over a week.

Wireless

Eleven-Year Solar Activity Period, Influence on Propagation of Wireless Waves. (H. Plendl, Proc. I. Rad. Eng., Vol. 30, No. 3, March, 1932, pp. 520-539.) (13.3/23527 U.S.A.)

From author's summary:—Researches concerning the propagation of short and border waves, conducted by the German Air-Travel Research Laboratory during the years 1930 and 1931, reveal results which are not quite in harmony with similar, but far more complete, investigations carried out in the years 1927-28.

The suspicion arises that one is here dealing with an influence exerted by the eleven-year period of solar activity upon the propagation of short and border waves, especially as such an influence upon long waves has been repeatedly established. The present work deals with the explanation of these phenomena.

Kennelly-Heaviside Layer Heights for Frequencies between 1,600 and 8,650 kc. per Second. (T. R. Gilliland, G. W. Kenrick and K. A. Norton, Bur. St. J. Res., Vol. 7, No. 6, Dec., 1931, pp. 1083-1104.) (13.31/23528 U.S.A.)

From authors' summary :—The results of observations of the height of the Kennelly-Heaviside layer carried out near Washington, D.C., during 1930 are presented. Evidence for the existence of two layers (corresponding closely in virtual height to the E and F regions discussed by Professor Appleton) is found during daylight on frequencies between three and five megacycles. The modification in the virtual height of the higher F layer produced by the existence of a low E layer is investigated theoretically, and the possibility of large changes in virtual height near the highest frequency returned by the E layer is pointed out. A number of oscillograms showing the characteristic types of records observed during the tests are presented together with a graph of average heights from January to October, 1930.

Phase and Amplitude Measurements of Electro-Dynamic Loud Speakers. (W. Binder, Phys. Zeit., Vol. 33, No. 2, 15/1/32, pp. 85-87.) (13.32/23529 Germany.)

A description is given of methods of measurement and typical curves are reproduced.

Simultaneous Radiotelephone and Visual Range Beacon for Airways. (F. G. Kear and G. H. Wintermute, Proc. I. Rad. Eng., Vol. 30, No. 3, March, 1932, pp. 478-515.) (13.6/23530 U.S.A.)

From authors' summary :—Increased use of the airway radio services by transport operators has resulted in a demand for continuous range beacon service. At the same time the weather broadcast information has increased in importance and the interruptions to beacon service have become more frequent. To eliminate difficulties arising from this conflict, a transmitting system has been developed which provides simultaneous transmission of visual range beacon and radiotelephone signals.

The transmitting set consists of a two-kilowatt radiotelephone transmitter operating into a non-directive antenna system and an additional set of amplified branches supplying power through a goniometer into two loop antennæ. The two antenna systems are symmetrically disposed with respect to each other and coupling effects are balanced out to prevent distortion of the space pattern. The phase of the currents in the different antenna systems is controlled by a phase-shift unit and means for checking the adjustment of this phase relationship continuously is provided.

The equipment on the aeroplane to receive this service is changed only by the addition of a small filter unit which keeps the low-frequency reed voltages from reaching the head telephones and the voice frequencies from the reed indicator.

Numerous flight tests on the system have shown it to provide very satisfactory service under adverse interference conditions.

Television. (C. O. Browne, J.I.E.E., Vol. 70, No. 423, March, 1932, pp. 340-353.) (13.7/23531 Great Britain.)

In a previous paper a graphical method of determining the magnitude and phase of the electric field in the neighbourhood of an aerial was developed on the

assumption that the effect of the aerial could be neglected. An indication was given of the development required for taking into consideration the image in the earth's surface. The method is now worked out more fully. A formula is deduced for the field near the earth's surface due to a doublet, with indications of its extension to the determination of the field at various distances. The polar distribution is shown graphically for eight arrangements of aerials, four with and four without reflector wires. A graphical representation of observed field strengths as a function of distance for given values of the dielectric constant, and varying values of the ratio of conductivity to frequency, exhibit the results as lying within a narrow band, which is taken as satisfactory.

Photography

Photograph Taken in the Dark by Infra-Red Light. (Ind. & Eng. Chem., Vol. 24, No. 1, Jan., 1932, pp. 8 and 12.) (14.10/13532 U.S.A.)

Photographs were taken on a special plate, hypersensitised with ammonia, of interiors in visual darkness illuminated with infra-red light by a battery of fifteen one-kilowatt lamps through a Wratten 87 filter screen. A photograph is reproduced.

Progress in Photogrammetry. (O. Lacmann, Z.V.D.I., Vol. 75, No. 33, 15/8/31, pp. 1047-1053.) (14.14/23533 Germany.)

A photographic survey department, equipped with the latest apparatus, has been set up in the Technical High School of Berlin in co-operation with D.V.L. Twenty-two photographs of apparatus are reproduced.

Acoustics

Measurement of Noise. (G. Bakos and S. Kagan, Z.V.D.I., Vol. 76, No. 7, 13/2/32, pp. 145-150.) (15.2/23534 Germany.)

From a large number of subjective measurements a scale of intensities is formed and exhibited graphically as a family of curves, from threshold intensity to 100 decibels and for frequencies from zero to 800 hertz. The upmost curve, with a different run indicates the intensity at which noise becomes painful. Mechanical apparatus for measuring intensity in terms of energy is described and records of observations are reproduced graphically and compared with the results obtained by Barkhausen's apparatus and by the method of comparison. The two former agree fairly well. The latter sometimes shows considerable discrepancies. Thirteen references are given.

Accidents

Aeroplane Accident Statistics, 1930. (L. Weitzmann, Z.F.M., Vol. 23, No. 1, 14/1/32, pp. 13-24, 264th D.V.L. Report.) (16.0/23535 Germany.)

An elaborate tabular and graphical analysis is given of the accidents occurring in Germany in 1930. There are 24 tables and 18 graphical diagrams covering a corresponding range of cross analyses. The elaborate statistics are not amenable to brief summarising.

Rocket Propulsion

Rocket Propulsion for Aeroplanes. (H. Oberth, Flug., No. 11-12, Nov.-Dec., 1931, pp. 1-3.) (17.2/23536 Austria.)

In order to obtain data for the ultimate design of a jet propelled aeroplane, considerable experiments will have to be carried out with rockets of the projectile type. These may be utilised to carry mails and would land by means of a parachute.

As these rockets increase in size they will become ultimately able to dispense with a parachute and land by gliding flight, the rocket being governed entirely by means of automatic apparatus. Only after these developments have been carried out will it be possible to design a man-carrying machine working on the same principle.

Gliding

Results of Rhon Gliding Competition, 1931. (W. Georgii, Z.F.M., Vol. 23, No. 4, 29/2/32, pp. 97-102.) (17.4/23537 Germany.)

Table I. gives particulars of eight duration flights which totalled 18¼ hours, the maximum of a single flight being 9 hours.

Table II. shows distances and heights flown in the performance competition. Distances vary from 31 km. to 120 km., and heights from 400 m. to 2050 m.

Two maps show the directions of the flights and the nature of the country traversed. Two diagrams show the position of cumulus clouds during the high-flying competition, with some indications of temperature gradients, moisture, etc.

Weather Conditions

Military Aviation in Indo-China. (Auphan, Rev. F. Aer., No. 30, Jan., 1932, pp. 3-10.) (19.1/23538 France.)

Conditions of operating aeroplanes in a tropical region are illustrated by numerous air photographs.

Meteorograph. (H. Kirsten, Z.V.D.I., Vol. 76, No. 5, 30/1/32.) (19.1/23539 Germany.)

A compact meteorograph with wireless sending apparatus for use in pilot balloons is described and illustrated by a photograph and a diagram. Temperature, pressure and humidity are measured on arcs of a graduated circle and the readings are transmitted by short wave. The design is the joint work of the D.V.L. Aeronautical Observatory, Lindenberg, and the Askania Works, Berlin. It was used on the Polar Expedition of the Graf Zeppelin and an example of the results obtained is quoted showing that up to 10.5 km. the temperature in the polar regions fell steadily and thereafter remained constant or increased slightly. This fixes the limit of the stratosphere at the given time and place to a height of 10.5 km. Five references are given.

Ice Prevention

Ice Prevention by Exhaust Heat. (T. Theodorsen and W. C. Clay, N.A.C.A. Report, No. 403, Feb., 1932.) (19.15/23540 U.S.A.)

A brief summary is given of previous work on the processes of ice formation and methods of preventing it. The application of exhaust heat has been postponed by the complications involved in design, construction and operation.

Part I. of the combined report deals with the elementary theory of the transfer of heat in which Nusselt's formula for pipes is used as a standard. The experimental arrangement of a model wing in the wind tunnel is fully described, with photographs. The rates of heat transmission from aerofoils with a source temperature of 54°F. for angles of incidence 0°, 6°, 12°, 18°, and for aerofoils of different sections, the velocities varying from 30 to 90 m.p.h., are given in seven diagrams; and two diagrams show the coefficient of heat loss per sq. foot per hour against the log of the speed.

In Part II. problems of design are considered. Three methods are applied :—

(1) Direct heating by exhaust gas.

(2) Supply of hot air direct from the cylinders of air-cooled engines or from air heaters in the exhaust pipe.

(3) Supply of steam from a small boiler heated from the exhaust pipe.

The circulation systems for the heating medium used in the experiments are shown by diagrams and photographs and conclusions are drawn for guidance in practical design. Ample heat is available from the exhaust or radiator and successful application is a matter of technical development.

Ice Hazard. (W. C. Gear, Aeron. Eng., Vol. 4, No. 1, March, 1932, pp. 33-36.) (19.15/23541 U.S.A.)

A brief account is given of the application of inflatable tubes on the leading edge, the deflation and inflation of which breaks up any ice formation. A diagrammatic drawing shows the method of mounting in the channel for research on ice formation. Nine references are given.

Matters affecting Pilots

Physiological Sensitivity to Vibrations (H. Reiher and F. J. Meister, Forschung, Vol. 2, No. 11, Nov., 1931, pp. 381-386.) (19.29/23542 Germany.)

Intensity is divided into classes: zero class, imperceptible; 1a, 1b, 1c, just perceptible, readily perceptible, and strongly perceptible; 2a and 2b, unpleasant and extremely unpleasant; the last two carrying risk of definite injury.

Experiments were carried out with a controllable platform and the observations are plotted on a log amplitude-frequency diagram which brings out the five classes as grouped along approximately straight line loci.

The Effect of Accelerations on Human Beings. (J. L. Nayler, J. Roy. Aer. Soc., Vol. 36, No. 255, March, 1932, pp. 251-254.) (19.29/23543 Great Britain.)

The author surveys a variety of conditions, including accidental falls, which impose accelerations rising to as much as 10 or 12 times gravity. These are compared with illustrative figures of stresses imposed by aerobatics.

Lighting

Air-Route Lights. (Franck, Rev. F. Aer., No. 30, Jan., 1932, pp. 68-80.) (21.095/23544 France.)

The elementary formulæ of illumination are given, and on this basis the required distribution of lights along a route is laid down.

Rules of navigation are tabulated for aircraft meeting under twelve possible conditions.

Fog Penetration

Fog, Transmission of Visible Infra-Red and Ultra-Violet Radiation. (S. H. Anderson, Aeron. Eng., Vol. 4, No. 1, March, 1932, pp. 1-12.) (21.22/23545 U.S.A.)

The elementary theory of absorption, scattering, diffusion and refraction is given, and the principal results are quoted.

A full technical investigation, illustrated by plan and end and side elevations, is given of the laboratory apparatus for producing artificial fogs in a chamber consisting of a 20-foot length of 6-inch steel pipe.

The fogs were prepared by expanding and cooling saturated air in the presence of tobacco smoke or tobacco smoke mixed with hygroscopic magnesium chloride. Moisture condensed on these particles and the diameter of drops selected by deposition on a small metal rod charged to high voltage was determined by micrometer microscope. The mean diameter of the drops thus determined is given as 6 micro-metres and 8 micro-metres respectively (micro-metre $= m \times 10^{-6}$).

A range of wave lengths, from 0.3 micro-m. to 2.64 micro-m. was covered by the investigations. This range was divided into fifteen sub-divisions corresponding approximately to ultra-violet, violet, blue, green, yellow, red and nine sub-divisions of the infra-red range.

The first eight sub-divisions were selected by use of light filters in conjunction with the selectivity of the photo-electric cells used for measuring intensity. The seven remaining sub-divisions in the ultra-red were obtained by spectrometer.

Five types of photo-electric cell and two types of thermo-pile were used for determining the intensity transmitted. Curves of transmission are given for different wave lengths and for different concentrations of fog particles. Minima were found in each case in the visible range with a slight rise in the ultra-violet range and a considerable rise on the ultra-red side.

Using appropriate photo-electric cells the energy received in the infra-red band was twenty times that received in the visual band.

Although the work carried out appears to be more complete and systematic than anything hitherto published a more reliable determination of the sizes of the water particles and a wider range of sizes is required to complete the investigation. This was admitted in the discussion of the discrepancy between the above results and observations made in natural fog. Ten references are given.

Light Signals in Aviation and Navigation. (I. Langmuir and W. F. Westendorp, Physics, Vol. 1, No. 5, Nov., 1931, pp. 273-317.) (21.22/23546 U.S.A.)

A comprehensive experimental investigation is made of the intensity of point light sources and diffused light sources for threshold visibility against a background of arbitrary intensity. As the background brightness increases the relative sensitivity of the eye for diffuse sources as compared with point sources decreases enormously. Photo-cells on the contrary record the total light received independently of its diffusion over an area, and the advantage increases very greatly with the background intensity. A description is given of a photo-electric receiver tuned to a diffuse light signal of given frequency. The receiver current is used to control a directional needle which indicates a change of 1.5 per cent. on an average brightness of about one-sixth of the visual threshold of the eye for a flashing point source with a completely dark background. The application of the method to diffuse light in a fog is discussed. The elementary mathematical equations are formed and solved. It is concluded that the instrument would be effective in a fog over a distance of several miles. A flashing arc beacon is described which is designed to throw a wide angle beam against a cloud or fog bank and thereby create a surface source of diffused light with economy of electrical power.

Aerodynamics and Hydrodynamics

The Conditions for Dynamic Similarity. (W. Herrmann, Z.V.D.I., Vol. 75, No. 20, 16/5/31, pp. 611-616.) (22.1/23547 Germany.)

An historical survey is made of the development of the conceptions of dynamical similitude, from Galileo and Newton to the present day. The characteristic non-dimensional expressions introduced by Newton, Froude, Reynolds and Cauchy, are formed, and some more general examples are discussed. Thirteen references are given.

Stability of Laminar Motion of Viscous Fluids. (A. Rosenblatt, Phil. Mag., No. 85, March, 1932, pp. 714-722.) (22.1/23548 Great Britain.)

A finite disturbance, vanishing exponentially both with time and distance, is assumed and the Stokes' function is written down to meet these conditions. A differential equation is formed and elaborate transformations and integrations are carried out largely in terms of Bessel functions. It is shown that the assumed

series for the Stokes' function is absolutely and uniformly convergent within a finite range and satisfies the conditions of viscous fluid motion.

(Abstractor's note :—The interpretation of the results as denoting stability of laminar flow under the assumed disturbance does not appear to be a necessary consequence).

Equations of Motion of a Viscous Fluid. (J. Prescott, Phil. Mag., No. 85, March, 1932, pp. 615-623.) (22.1/23549 Great Britain.)

The author criticises proofs based on the analogy with elastic theory and the assumption of Stokes' proof that there is a linear relation between stress and rate of strain. He proceeds from the simplest case of motion in parallel plane laminæ with uniform velocity gradients, introducing Stokes' assumption of a linear relation between rate of strain and stress in this particular case. He builds up 2-dimensional and finally 3-dimensional relations step by step, each step tacitly involving Stokes' assumption. The proof does not appear to differ in any essential particular from that given in Lamb's Hydrodynamics and merely postpones the formation of expressions involving 3-dimensional strain.

Slow Motion of Fluids. (W. R. Dean, Phil. Mag., No. 85, March, 1932, pp. 585-600.) (22.1/23550 Great Britain.)

The application of a method of bi-harmonic analysis by Professor A. E. H. Love, is considered with reference to the analogy with slow motion of viscous fluids, particularly in 2-dimensional flow past obstacles. A considerable development of the analysis is carried out in application to 2-dimensional flow through a channel partly closed by a vertical barrier.

The Flow in a Water Turbine. (F. Busmann, Forschungsheft, No. 349, Oct., 1931.) (22.1/23551 Germany.)

A description is given with a diagram and photographs of an experimental turbine and methods of exploring the velocity field. The usual equations of reaction and hydraulic efficiency are formed and a large number of experimental values of pressure distribution and velocity is given in over 50 diagrams. The direction of flow is indicated by the etching of the blades by the stream. By use of a cylindrical glass casing visual and photographic observations of the flow were made. Comparisons with 2-dimensional results obtained by conformal transformation were unsatisfactory. Comparison with the polar curves of individual profiles gave fair agreement. Seventeen references are given.

Quasi-Laminar Flow. (R. L. Peek and W. R. Erickson, Bell Tele. B.632.) (22.1/23552 U.S.A.)

The authors discuss departure from Poiseuille's law by some plastic fluids. The modifications due to transition from viscous to plastic flow are developed by an approximate semi-empirical method for flow down a cylindrical tube and compared with the Bingham-Buckingham formula. The physical implications of the theoretical treatment are discussed. A large number of experimental results is tabulated and exhibited graphically. The difficulties of interpretation are made clear.

Physical Concepts of Plastic Flow. (R. L. Peek and D. A. McLean, Bell Tele. B.633.) (22.1/23553 U.S.A.)

The physical considerations of the foregoing abstract are discussed at greater length along similar lines. A more general form of Bingham's equation is presented and three examples of delivery against pressure are plotted for different assumed values of the coefficients. A still more elaborate form is assumed with three arbitrary coefficients and examples are plotted of the result of fitting the

equation to experimental values. In ordinary viscous flow the delivery is proportional to the pressure gradient. The experimental results for semi-plastic substances exhibit the delivery as increasing rather more rapidly than the pressure difference. There is obviously no difficulty in fitting an expression with three arbitrary coefficients to experimental curves of this simple nature. The physical interpretation of the coefficients is not obvious.

Flow through Nozzles and Orifices. (R. Witte, Z.V.D.I., Vol. 75, No. 48, 28/1/31, p. 1454.) (22.2/23554 Germany.)

Pressure measurements at the wall of the tube are subject to the effects of compression or expansion of the air as it passes through the metering device. The author investigated the distribution of pressures over a wide range and found that the standard German metering devices, properly used, showed errors not exceeding 1 per cent.

Flow in Roughened Tubes. (J. Nikuradse, Z.A.M.M., Vol. 11, No. 6, Dec., 1931, pp. 409-411.) (22.2/23555 Germany.)

Tubes were roughened by dusting the inner surface with sand grains. Taking k to denote the mean size of the grains and r the diameter of the tube the resistance was determined for four values of k/r for a range of Reynolds numbers from 2.6 to 6.0.

For the largest value of k/r there is a rapid transition from laminar flow to turbulent flow. For the lowest value there is an intermediate range in which Blasius' relation is satisfied (resistance varies as $r^{-\frac{1}{4}}$) with rapid transition to the final state, resistance proportional to the square of the velocity.

For $k/r=0.0328$ the contract of the experimental curve with the straight line representing Blasius' relation is shorter and the transition to the final state is slower.

For $k/r=0.0163$, after a slight tendency to follow the Blasius relation the curve passes more rapidly to the final state.

Flow of Compressible Liquid in a Wind Channel. (S. G. Hooker, Proc. Roy. Soc., Vol. 135, No. A.827, 1/3/32, pp. 498-511.) (22.4/23556 Great Britain.)

A convergent-divergent nozzle formed by rotating an arc of a circle about an external axis parallel to the chord is discussed by means of a method due to J. I. Taylor. The velocity potential is expanded in series satisfying (1) the conditions of symmetry of flow with respect to the axis of rotation and to the plane of symmetry of the nozzle at right angles to the axis; (2) the former condition only. The constants are determined by equating coefficients and numerical results are calculated. Graphical representations are also given and appear to give a good fit with points plotted from Stanton's experimental work.

Eddy Diffusion in the Atmosphere. (O. G. Sutton, Proc. Roy. Soc., Vol. 135. No. A.826, 1/2/32, pp. 143-165.) (22.4/23557 Great Britain.)

The work of G. I. Taylor, L. F. Richardson and W. Schmidt, the resulting differential equation used by Taylor and Schmidt, and the suggested solutions are discussed by purely statistical methods. Expressions are given for instantaneous and continuous point and line sources. The results are compared with experiments on scattering of groups of balloons and on smoke diffusion. A particular form of the general solution is obtained which fits fairly well with most observations up to distances of 600 km.

Flow of Gases at Low Pressures. (H. Ebert, Phys. Zeit., No. 4, 15/2/32, pp. 145-151.) (22.4/23558 Germany.)

Transition from types of flow indicated by hydrodynamical theory when the mean free path is small compared with the dimensions of the conduit, to " molecular flow," where the mean free path is large compared with the dimensions of the tube, is discussed mathematically, and experimental results are tabulated and drawn graphically for comparison. Fifteen references are given.

Gap Losses at Aerofoil Tips. (O. Flachsbart, Z.A.M.M., Vol. 11, No. 6, Dec., 1931, pp. 411-414.) (22.4/23559 Germany.)

Water turbine blades rotating with their tips near the casing present a problem in induced resistance analogous to that of an aerofoil of span nearly equal to the width of the channel in which it is mounted.

For small gaps (1 cm. and less) the measured " gap loss " (the proportional increase of resistance) is less than the calculated figure. As might be expected the thicker the wing the greater is the deficiency. Above 1 mm. the observed values approach the calculated curve asymptotically.

The flow of air through the gap is shown diagrammatically with and without end plates on the wing. Two photographs are reproduced with $TiCl_4$ as indicator.

Turbulent Motion in Tubes, Experimental Investigation. (A. Naumann, Forschung, Vol. 2, No. 3, March, 1931, pp. 85-98.) (22.5/23560 Germany.)

The flow of water in a glass tube was recorded by cinematograph for different Reynolds numbers. Special attention was paid to the inflow portion of the tube. The entry has two critical numbers, the lower corresponding to the beginning of a periodic vortex street and the higher critical number corresponding with the setting up of general turbulence. There is a relationship between the flow in the tube entry and that existing round a body in a stream. Both flows go through the same history—laminar flow, vortex street, turbulence.

The amount of disturbance reaching the stream from the so-called inlet vortex can be estimated from the vortex distance and contraction. General turbulence begins when the circulation of the introduced disturbance is approximately equal to that of the existing velocity profile. This also holds for the inlet region and is in agreement with the known increase of the critical number with a shortening of the lead in.

The Flow of Gases through Throttling Devices. (W. Nusselt, Forschung, Vol. 3, No. 1, Jan.-Feb., 1932, pp. 11-20.) (22.5/23561 Germany.)

In discussing the application of dynamical similitude, the equations of viscous fluid motion and of continuity, the equation of condition for a gas, and the adiabatic conservation of energy equation are used. From the form of these equations six non-dimensional parameters are obtained by means of which the relations between pressure and delivery are expressed non-dimensionally. The expression is found for the delivery under adiabatic expansion and this quantity divided by Poiseuille delivery is taken as the coefficient of the nozzle. Experimental values of delivery and contraction are plotted against the pressure drop and lie fairly well on unicursal curves. The critical pressure drop ratio for air is found to be 0.245. For well rounded nozzles the critical ratio is 0.528.

Elasticity of Materials

Box Girders, Torsional Stiffness, Theoretical and Experimental Investigation. (S. F. v. Boutteville, Forschung, Vol. 3, No. 1, Jan.-Feb., 1932, pp. 25-42.) (23/23562 Germany.)

Prandtl's soap-film analogy is referred to in respect of its experimental difficulties, and Kelvin's hydrodynamical analogy is preferred as giving more useful

results. The method depends on choice of approximations, which are given in an original form and applied to a number of examples. The numerical results to first and second approximations are tabulated for comparison with experimental results, the discrepancy being generally well within ±10 per cent. with occasional slightly higher values. A number of fields of stress are shown graphically.

Safety in Structural Design. (A. Thum, Z.V.D.I., Vol. 75, No. 23, 6/6/31, pp. 705-708.) (23/23563 Germany.)

Maximum stress does not necessarily occur at minimum cross section, and additional grooves may reduce the stress maxima. Notch test results vary widely with material. Notched high tensile silica steels may have ultimate fatigue strength no higher than softer steels, with one-third of the ultimate tensile strength under steady loads.

In design of springs a softer steel may give better fatigue results than a high tensile steel.

Residual Stresses in Cold Drawn Tubes. (N. Dawidenkow, Z. Metallk. Vol. 24, No. 2, Feb., 1932, pp. 25-29.) (23/23564 Germany.)

Specimens are cut from portions of the tube after drawing, and changes in curvature, etc., due to internal stresses, are measured. Successive thin layers are dissolved from the inner and outer surfaces and changes in diameter are measured. Sufficient data having been accumulated, the determination of the residual stresses is discussed mathematically. The results are compared with experiment and the comparison is shown graphically.

Fatigue Tests of Nickel Tubing for Fuel Pipes. (R. Worthington, Autom. Ind., Vol. 66, No. 5, 30/1/32, p. 164.) (23/23565 U.S.A.)

Curves of resistance under repeated loadings are given for annealed and unannealed copper and nickel pipes. The tests were carried out by the U.S. Army Air Corps, Wright Field. The numerical ratio in favour of nickel is striking, two comparative figures quoted being $40\frac{3}{4}$ hours for nickel and $5\frac{1}{2}$ hours for copper, both annealed; and $91\frac{3}{4}$ hours for nickel and 8 hours for copper, both unannealed.

Properties of Some Materials under Dynamic Loads. (M. Hempel, Forschung, Vol. 2, No. 9, Sept., 1931, pp. 327-334.) (23/23566 Germany.)

Some steel, brass and aluminium specimens were subjected to loads by setting loaded rods in vibration. The internal hysteresis was investigated by observing the time decrement under various conditions over a range of amplitudes. A number of results is recorded graphically. Photographs of typical fractures are reproduced. The gradual change of the elastic limit by hardening is brought out and the course of development of fractures is discussed.

Miscellaneous Unclassified

Symbolic Calculus. (B. van der Pol and K. F. Niessen, Phil. Mag., No. 85, March, 1932, pp. 537-577.) (23567 Great Britain.)

The authors prefer J. R. Carson's nomenclature and point of view (Electric circuit theory and operational calculus, 1926) to the notions of operator and operand in the original sense of Heaviside's operational calculus. The relation between the " original " function and its " image " is defined by an integral equation of a special type. The rules for reduction and transformation are given. A large number of applications are given and include summation of series, expression of B functions in terms of gamma functions, evaluations of integrals, particularly those involving Bessel functions.

Aircraft as an Instrument of Polar Research. (W. Bruns, Z.F.M., Vol. 23, No. 3, 15/2/32, pp. 65-72.) (23568 Germany.)

The subject is discussed in general terms and also with reference to the recent expedition of the Graf Zeppelin. The instrument equipment is described and illustrated by several photographs. An example of photogrammetric mapping is reproduced, the course of the ship and the positions of the photographic exposures being shown on the map.

Comparison of European and American Air Lines. (P. Goldsborough, Luftwacht, No. 12, Dec., 1931, p. 534.) (23569 Germany.)

The author (President of Northern Air Lines (U.S.A.)) travelled much on European air lines in 1930. The slower speed, less comfort and absence of passenger night flying are noted.

Political frontiers in Europe raise difficulties of language and regulations unknown in U.S.A.

Statistical Survey of Aircraft Industry. (Aviation, Vol. 31, No. 3, March, 1932, pp. 101-139.) (23570 U.S.A.)

A series of statistical articles gives a comprehensive survey of commercial aviation activities in U.S.A. covering air routes in operation, number of passengers carried, mail subsidies (nearly $20,000,000 in 1931), seasonal distribution of the flights, regularity coefficient and accidents, aviation schools licensing requirements in various States, distribution of licences, aircraft pilots and mechanics. A brief note is given on military and naval activities. Statistics are given of Canadian and European activities.

Refuelling—U.S.A. (Luftwacht, No. 12, Dec., 1931, p. 545.) (23571 Germany.)

During last year's manœuvres, fuel tank wagons were successfully employed. Each wagon can supply three aircraft simultaneously up to 40 gallons a minute. In Cleveland 110 reconnaissance machines were fuelled in under two hours.

The Development of American Civil Aviation. (Luftwacht, No. 12, Dec., 1931, p. 537.) (23572 Germany.)

In the U.S.A. there are 136 lines in regular operation under control of 43 companies. The most favoured machine is the single engine 500 h.p. eight-passenger cabin type with a single pilot, who also operates the wireless installation. Over long distances the pilots are changed but the machine goes on. On variable traffic the multi-engined aircraft carrying 15-20 passengers is less economical.

German-Russian Civil Aviation. (Luftwacht, No. 12, Dec., 1931, p. 537.) (23573 Germany.)

On November 23rd, 1931, the Deruluft Aviation Company completed its tenth year of service. During the past year over 3,600 passengers and 145 tons of post and goods have been carried on its two main routes, Berlin-Moscow and Konigsberg-Leningrad.

Development of More Rapid Post and Passenger Services on German Air Lines. (E. Schatzki, Z.F.M., Vol. 23, No. 1, 14/1/32, pp. 1-6.) (23574 Germany.)

A large number of statistics of aeroplanes and engines are tabulated and plotted graphically. A selection of the most suitable combinations for German air lines is discussed on the basis of these statistics.

Military Air Ambulances. (Beyne, Rev. F. Aer., No. 30, Jan., 1932, pp. 81-94.) (23575 France.)

The article is a lengthy precis of a paper in the archives De Medecine et de Pharmacie Militaires, December, 1931, discussing the scope of aeroplane ambulances in war. An analysis is given of statistics from the war classifying the wounded according to the degree of urgency of treatment, and hence of priority for air transport to hospital.

Aircraft for Ambulance Service. (Tech. Aeron., No. 121, Nov., 1931, pp. 287-291.) (23576 France.)

Reference is made to the offer of an award for aeroplane ambulances for military service. Desirable qualities are briefly specified and a list of aeroplanes designed or adapted to the purpose is given with brief details of their capacity. Experiences in Syria and Morocco are quoted. The allotment of ambulance aeroplanes to units is outlined by a medical officer. Requirements in time of war in competition with military demands could only be drawn from the available reserve of commercial machines.

General Maintenance. (H. C. Downey, Aeron. Eng., Vol. 4, No. 1, March, 1932, pp. 21-32.) (23577 U.S.A.)

A large number of useful hints are given for mechanics, inspectors, and ground engineers. Four references are given.

Application of Soft Rubber to the Production of Graphical Stress Fields. (H. Stoll, Forschung, Vol. 2, No. 9, Sept., 1931, pp. 313-318.) (23578 Germany.)

The two-dimensional problem is discussed. The plain surface of the unstrained rubber is ruled with a net-work of squares and is photographed before and after the application of the selected stress conditions. The ease of mapping the strain field is offset by the rapid departure from proportionality of strain and stress with increasing load and the consequent difficulties of interpretation in terms of stress. Seven references are given.

Optical Glass in America. (H. F. Kurtz, Vol. 12, No. 70, Jan.-Feb., 1931, pp. 251-254.) (23579 U.S.A.)

A brief descriptive account with eight photographs is given of the optical glass industry in America, the creation of which was due to war conditions. The difficulties met with and the poor average quality produced during the war are fully discussed. Apparently only one manufacturing plant remains, the average product of which is stated to exceed the European standards. Experimental optical glasses are produced on a small scale at the Bureau of Standards.

Oil Pipe Coupling. (Autom. Tech. Zeit., Vol. 34, No. 15, 31/5/31, p. 364.) (23580 Germany.)

A description with a diagram is given of an oil pipe coupling in which a union is locked by means of two spring levers of the type commonly applied to bottle stoppers. The levers force the conical ends of the pipes to be coupled on to a short union pipe with a double conical rubber washer. It is stated that pipe breakages are much reduced by the device.

AERIAL SURVEYING IN NORTHERN RHODESIA*

BY

W. NORMAN ROBERTS, F.R.G.S., A.F.R.Ae.S.

Introduction

One of the most recent and important branches of aeronautics is aerial survey. During the last seven or eight years great improvements have taken place which have developed it into a science of its own. Several aerial survey companies are now operating in various parts of the world, and the untiring and persistent manner in which these pioneers have succeeded in overcoming difficulties has been crowned with success, as it is now accepted by most governing powers as a useful, economical and quick method of surveying.

Before discussing the actual methods of aerial survey it might be as well to consider some of the advantages of this new science, and these can be summarised as follows:—

(*a*) The use of aerial survey in the development of the Empire.
(*b*) The low cost and the speed at which reconnaissance surveys can be carried out in new countries which are almost inaccessible by ground methods.
(*c*) The advantage of gaining more topographical detail than could be collected by ground instruments.
(*d*) The value to the engineer of overlapping stereoscopic photographs.

One of the first steps in Empire development is to secure reasonably accurate maps of the country, which, in most cases, if done by ground methods, is a long and costly undertaking. A good example of this is Northern Rhodesia, which is, generally speaking, a flat, densely-wooded country, where plane-tabling and triangulation are almost impossible. From aerial photographs of such a country, however, the main drainage, types of vegetation and most of the topographical details can be obtained in some accurate relationship to each other. It therefore remains for the scientist to discover some method of utilising the information on these photographs for the purpose of producing maps.

The low cost and speed at which reconnaissance maps can be produced has been sufficiently proved by the fact that the Northern Rhodesian survey of 63,400 square miles will be completed within twenty months, whereas it is estimated that the same work, giving possibly less topographical detail, would take ground parties anything from fifteen to twenty years, and cost approximately three times as much.

It can be readily appreciated that even a detailed topographical survey map could not possibly contain the same amount of detail as would be shown in a vertical photograph of the same area. The amount of detail the ground surveyor records, depends firstly on the nature of the survey and secondly on the scale of the final plot. For instance, if he were surveying for a weir, he would not waste the time or money in recording the position of buildings, etc., which would not affect the weir. When, however, a photographic map is made it contains a complete record of all topography visible from above, all of which is bound to be useful at some future date.

Air survey is further of great use to the town engineer, particularly abroad, where towns have grown up with such rapidity that records of all buildings, etc., have not been made on the town plans. With the aid of vertical photographs these plans can be brought up to date at a very small cost. The town engineer

* Received September, 1931.

can also investigate most of his engineering problems, such as drainage, etc., by examining stereoscopic photographs which enable him to appreciate the contours of the area, in the same way as if he were examining a model in relief. There have been numerous cases where the preliminary cost of investigating some engineering project has been so high that the matter has had to be shelved, whereas most of such schemes could have been thoroughly investigated in the office from the mosaic and stereoscopic photographs at a very small cost.

On the other hand, one must realise that aerial survey has its limitations. Unfortunately, it is still believed by some that it will replace ground methods in the future, and consequently seriously affect the land surveyor. As a matter of fact, it has been proved, particularly in Canada, that, as a result of aerial surveys, there has been more scope for the land surveyor. The errors introduced by tilt, lens distortion, height displacements, shrinkage and expansion of photographic paper and film, etc., are far greater than any errors obtained when using the latest theodolite or tachometer. Therefore, those contemplating aerial surveys should be prepared to accept results which contain certain minor errors, but, at the same time, realise they are obtaining maps which show more valuable information and detail than is usually recorded.

The Northern Rhodesia Survey

On plate No. 1 the portion of Northern Rhodesia which has been surveyed

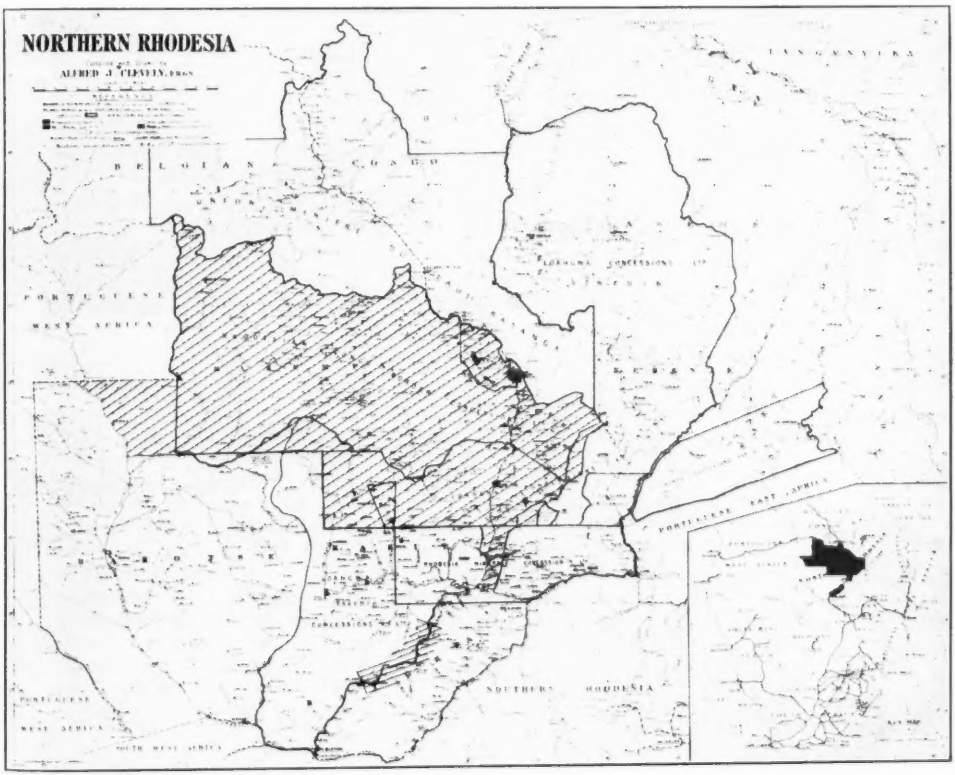


PLATE 1.

by oblique photographs, is shown cross-hatched. It is through this area that the main copper belt runs, and consequently, during the past few years, a considerable amount of development has taken place. The existing maps of the country, however, were most unreliable, and in order to have the country more accurately surveyed in a reasonably short space of time, the Aircraft Operating Company, Ltd., contracted to deliver maps on a scale of 1/250,000 of 63,400 square miles by the 30th September, 1931.

The expedition set out from England in February, 1930, arriving at Broken Hill, the main base, during March, and proceeded immediately to organise field operations in order to complete the flying before the rains set in.

Equipment

It was considered advisable that a special aeroplane should be constructed for this contract, for the following reasons:—

(*a*) A multi-engined aircraft with a duration of, at least, seven hours was necessary, as the country is densely wooded and the cost of constructing aerodromes prohibitive.

(*b*) The aircraft should be specially constructed to take two cameras, one for oblique and one for vertical photography.

(*c*) Ample space should be provided for the pilot, and more particularly the photographer, to operate in comfort.

The Gloster Aircraft Company, therefore, constructed the "Gloster Survey" aeroplane, and the following are a few of the leading features:—

(1) All-metal structure.

(2) Two 460 h.p. Bristol Jupiter XI engines, with a gear ratio of 2 to 1. These were low compression to allow of operation with ordinary commercial petrol, if necessary.

(3) Performance. The aircraft could maintain a height of 9,000 feet, with full load, on any one engine.

(4) The range was between 6½ and 7 hours at an altitude of 20,000 feet, after having reached that height.

(5) Maximum ground speed 140 m.p.h. Speed, at 20,000 feet, 110 m.p.h. Stalling speed 45 m.p.h.

(6) Survey load 800 lbs. Total load 9,000 lbs.

(7) Dual control was fitted in such a way that the pilot could control the aeroplane from either side of the cockpit.

(8) Among other special features were gas starters, petrol pumps, a glass floor in the front of the machine to enable the observer to check the photographic overlap and also observe for drift. Plate No. 2 is a photograph of the "Gloster Survey." "Eagle" aerial cameras, manufactured by the Williamson Manufacturing Company, were used on this survey. On the oblique work they were fitted with a seven-inch-wide angle lens. The film magazines each held a roll of film about 65 feet in length and nine inches in width, on which 100 exposures, each measuring seven inches square, could be made. Attached to the side of the camera body was the instrument box, which contained the following: (1) Veeder counter; (2) aneroid, registering 500 feet on either side of the selected altitude; (3) the company crest; (4) a 30-hour watch; (5) an ivory tablet on which could be written such particulars as date, area, filter, stop, and the pilot and photographer's names.

The camera was operated by an electric control box, which automatically wound the focal plane shutter and released it at the regular time interval. It

also illuminated a red light, attached to the pilot's instrument board, five seconds before each exposure, which enabled him to correct for any tilt or excessive drift.

Unfortunately, this control box was not reliable and frequently ceased to function a short time after commencement of photography. It was concluded that the reason for this was that the box had not been designed to function at very low temperatures for any length of time, and as no time could be spared to rectify this trouble, the photographer had no option but to operate by hand.

All the film was developed in the field, and for this purpose a caravan-trailer was constructed and fitted with a projector, developing tanks, sinks, contact printer, etc. By means of the new Williamson developing tanks, which require

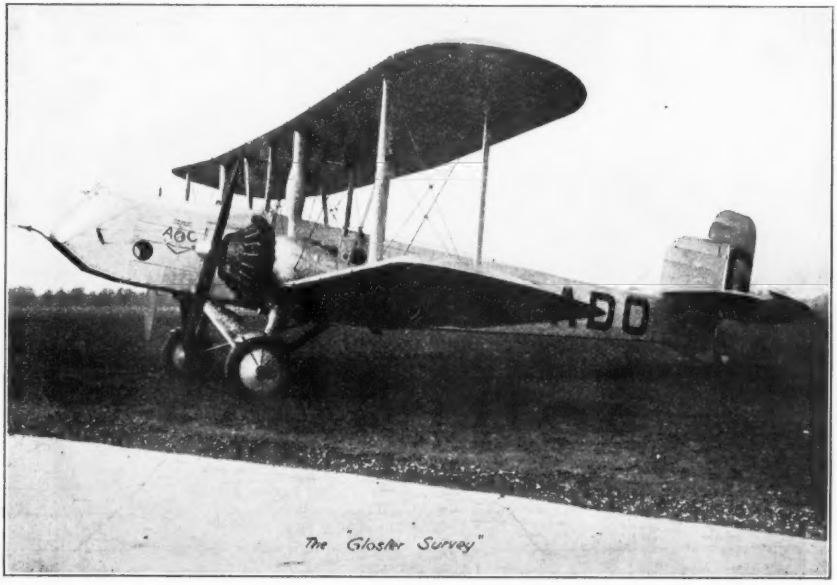


PLATE 2.

only a small quantity of solution and are easily handled, the films were developed with speed and economy. When washed, the wet films were dried in an hour by winding them round a drying drum, which was rotated at a great speed.

Field Operations

The first field operation is the vertical photography along strips about thirty miles apart, on which the ground surveyors fix control points by means of the prismatic astrolabe and wireless time signals. Plate 3a shows the position and amount of vertical photography necessary to control the whole area for scale. From the flying point of view this was probably one of the most difficult operations, because, as previously mentioned, the existing maps of the country were unreliable and the result of these control strips depended on skilful navigation. As soon as each vertical flight was completed the films were developed and one set of contact prints was supplied to the ground surveyor, who was instructed to locate himself on the photographs and fix a control point every thirty miles. The distance between control points depends on the accuracy required in the final plot. It has been found by experience that 35 contact photographs can be

traversed by the " centre point " or " Arundel " method without exceeding a maximum error of $\frac{1}{4}$in. and therefore using a 7in. lens from an altitude of 12,000 feet, the scale of each photograph $=h/f=12{,}000/7=1{,}714$ feet equal one inch. The effective forward gain by each photograph with a 60 per cent. overlap equals $1{,}714\times7\times40$ per cent. $=4{,}799$ or, say, 4,800ft. The number of miles covered by 35 exposures equals

$$(35\times4{,}800)/5{,}280=32 \text{ miles approx.}$$

The above error of $\frac{1}{4}$ inch is developed when traversing at a scale of one inch $=1{,}714$ feet, but as the scale of the final plot is 1/250,000, this error is

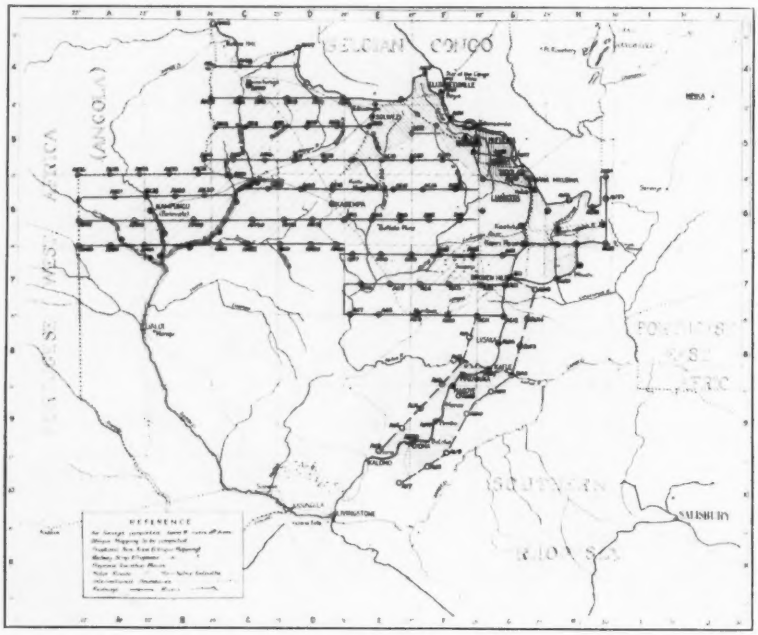


PLATE 3A.

Showing lines of vertical photographic control strips. Astronomical points shown circled.

reduced to 1/50in. It was therefore decided to make the distance between control points 30 miles.

Apart from fixing control points each ground surveyor was instructed to interpret as much detail on the photographs as possible and also supply the names of all rivers and villages he came across.

His observations included:—

1. Determining the latitude and longitude of each point.
2. The barometric height.
3. The magnetic declination.

Provided the weather was suitable, each surveyor took five days per point, that is, two nights for observing and three days on the march, but as may be expected there were many cloudy nights and it was feared at one time that the control programme would be seriously behindhand.

Another advantage of having a set of photographs with him was that the surveyor was able to locate the actual print for the next observation, 30 miles away, by scaling the photographs. On arrival at his destination he first prepared a programme of stars which enabled him to observe three stars in each quadrant at intervals of fifteen to twenty minutes. Provision had to be made to get, at least, two time signals from European stations, preferably at 4 p.m. and 10 p.m. on the day of observation, in order to determine accurately the error and rate of the chronometer.

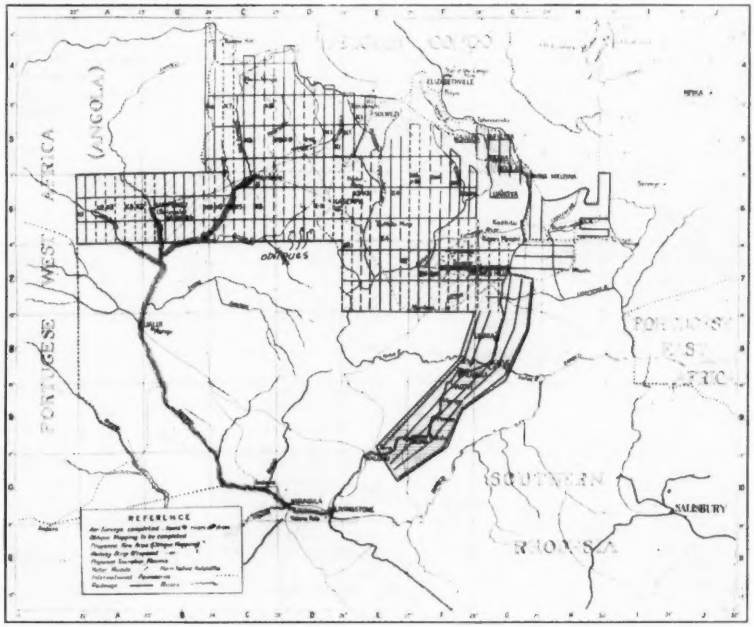


PLATE 3B.
Showing position of oblique photo strips.

The actual observation is the accurate recording of the time, by means of a stop watch, when the star reaches an altitude of 60°. This is simplified by means of the prismatic attachment which duplicates the image of the star in the field of vision. These two images appear to approach each other fairly rapidly and coincide when the star is at an elevation of 60°.

The results of the observations are then computed as shown herewith and only if the surveyor is satisfied that any two sets of four stars, one in each quadrant, give results which do not differ by more than 1½ seconds of arc, he then proceeds on to the next point. One-and-a-half seconds of arc being approximately 150 feet at a scale of 1/250,000 can hardly be regarded as a plotable error.

The final result is obtained graphically by assuming the latitude and longitude and plotting lines at right angles to the azimuths of the stars along the assumed latitude at distances which represent the difference between the true and assumed longitude of each star. The mean position is then obtained by locating the centre of a circle which can be symmetrically placed between any one set of four stars. An example of the final plot is also attached.

L.M.T. & LATITUDE FROM ALTITUDES OF STARS WITH A PRISMATIC ASTROLABE.

Name of Star ε Cen. Photo No. 03830. Station AC13.

	° ′ ″	h. m. s.	
Approx. lat. ...	13 11 45S.	Approx. long. ... 1 51 20E.	Date 16/5/31.
	h. m. s.		h. m. s.
Chron. time ...	6 33 30		R.A. Star ... 13 16 44.47
Stop watch ...	6.5		° ′ ″
			90 00 00
Time of pass ...	6 33 23.5		
Chron. error ...	6 35.28		Star's decl. ... 36 21 14.77
G.M.T. of pass	6 26 48.22		Star's polar dist. 53 38 45.23
	° ′ ″		
Star's alt. ...	59 59 30		
Latitude ...	13 11 45	Log. sec ... 10.0116214	
Polar dist. ...	53 38 45.23	Log. cosec ... 10.0940052	
2)	126 50 00.23		
Half Sum ...	63 25 00.11	Log. cosin ... 9.6507915	Log. cos decl. = 9.9059948
Altitude ...	59 59 30		Log. sin H.A. = 9.5598473
½ S-A	03 25 30.11	Log. sin ... 8.7762819	Log. sec alt. =10.3009206
		Log. sin sq. ... 38.5327000	Log. sin az. = 9.7667627
		Log. sin ½ H.A. 9.2663500	
		° ′ ″	° ′ ″
		Half H.A. ... 10 38 26.69	Az. =35 45 56.23
		Therefore H.A. =21 16 53.38	

	h. m. s.
21° =	1 24
16m. =	1 04
53.38s. =	3.55
And H.A. in T. =	1 25 07.55
Star's R.A. =	13 16 44.47
R.A. meridian =	11 51 36.92
L.S.T. of L.M.N. =	15 32 38.60
Sid. Int. from L.M.N. =	8 18 58.32
M.T.Eq. h.	7 58 41.36
m.	17 57.05
s.	58.16
Calc. L.M.T. ...	8 17 36.57
G.M.T. of pass	6 26 48.22
Long. in time	1 50 48.35
Long. in arc ...	27 42 05.25

L.M.T. & LATITUDE FROM ALTITUDES OF STARS WITH A PRISMATIC ASTROLABE.

Name of Star °Vir. Photo No. 03830. Station AC13.

		° ′ ″			h. m. s.		
Approx lat.	...	13 11 45S.	Approx. long.	...	1 51 20E.	Date 16/5/31.	
		h. m. s.					h. m. s.
Chron. time	...	5 23 00				R.A. Star	... 12 01 43.31
Stop watch	...	5.8					° ′ ″
Time of pass	...	5 22 54.2					90 00 00
Chron. error	...	6 35.09					
G.M.T. of pass		5 16 19.11				Star's decl.	... 9 06 51.07
		° ′ ″				Star's polar dist.	99 06 51.07
Star's alt.	...	59 59 30					
Latitude	...	13 11 45	Log. sec	...	10.0116214		
Polar dist.	...	99 06 51.07	Log. cosec	...	10.0055182		
		2) 172 18 06.07					
Half sum	...	86 09 03.03	Log. cosin	...	8.8269162	Log. cos decl.	= 9.9944818
Altitude	...	59 59 30				Log. sin H.A.	= 9.5384211
½ S-A	...	26 09 33.03	Log. sin	...	9.6443071	Log. sec alt.	= 10.3009206
			Log. sin sq.	...	38.4883629	Log. sin az.	= 9.8338235
			Log sin ½ H.A.		9.2441814		
					° ′ ″		° ′ ″
			Half H.A.	...	10 06 19.83	Az.	= 43 00 17.78
			Therefore H.A.		= 20 12 39.66		
					h. m. s.		
				20° =	1 20 00		
				12m. =	48		
				39.66s. =	2.64		
			And H.A. in T.		= 1 20 50.64		
			Star's R.A.		= 12 01 43.31		
			R.A. meridian		= 10 40 52.67		
			L.S.T. of L.M.N.		= 15 32 38.60		
			Sid. Int. from L.M.N.		= 7 08 14.07		
			M.T.Eq.	h.	6 58 51.19		
				m.	7 58.69		
				s.	14.03		
			Calc. L.M.T.	...	7 07 03.91		
			G.M.T. of pass		5 16 19.11		
			Long. in time		1 50 44.80		
			Long. in arc	...	27 41 12		

L.M.T. & LATITUDE FROM ALTITUDES OF STARS WITH A PRISMATIC ASTROLABE.

Name of Star ι Leo. Photo No. 03830. Station AC13.

Approx. lat. ... 13° 11′ 45″S. Approx. long. ... 1 h. 51 m. 20 s. E. Date 16/5/31.

Chron. time ...	4 h. 50 m. 35 s.		
Stop watch ...	9.2		
Time of pass ...	4 50 25.8		
Chron. error ...	6 39.98		
G.M.T. of pass	4 43 50.82		
	° ′ ″		
Star's alt. ...	59 59 30		
Latitude ...	13 11 45	Log. sec ...	10.0116214
Polar Dist. ...	100 54 29.49	Log. cosec ...	10.0079187
	2) 174 05 49.49		
Half Sum ...	87 02 52.24	Log. cosin ...	8.7118238
Altitude ...	59 59 30		
½ S-A	27 03 22.24	Log. sin ...	9.6578814
		Log. sin sq. ...	38.3892453
		Log. sin ½ H.A.	9.1946226
		° ′ ″	
		Half H.A. ...	9 00 21.85
		Therefore H.A. =	18 00 43.70

	h. m. s.	
18° =	1 12	
m. =	— —	
43.70s. =	2.90	
And H.A. in T. =	1 12 02.90	
Star's R.A. =	11 20 21.22	
R.A. meridian =	10 08 18.32	
L.S.T. of L.M.N. =	15 32 38.60	
Sid. Int. from L.M.N. =	6 35 39.72	
M.T.Eq. h.	5 59 01.02	
M.T.Eq. m.	34 54.27	
M.T.Eq. s.	39.61	
Calc. L.M.T. ...	6 34 34.90	
G.M.T. of pass	4 43 50.82	
Long. in time	1 50 44.08	
Long. in arc ...	27 41 01.2	

	h. m. s.	
R.A. Star ...	11 20 21.22	
	90 00 00	
Star's decl. ...	10 54 29.49	
Star's polar dist.	100 54 29.49	
Log. cos decl. =		9.9920813
Log. sin H.A. =		9.4902655
Log. sec alt. =		10.3009207
Log. sin az. =		9.7832675
	° ′ ″	
Az. =	37 22 50.98	

L.M.T. & LATITUDE FROM ALTITUDES OF STARS WITH A PRISMATIC ASTROLABE.

Name of Star ε Cen. Photo No. 03830. Station AC13.

	° ′ ″		h. m. s.		
Approx. lat. ...	13 11 45S.	Approx long. ...	1 51 20E.	Date 16/5/30.	
	h. m. s.				h. m. s.
Chron. time ...	9 23 20			R.A. Star ...	13 16 44.47
Stop watch ...	11				° ′ ″
Time of pass	9 23 09				90 00 00
Chron. error ...	6 35.77			— Star's decl.	36 21 14.77
G.M.T. of pass	9 16 33.23			Star's polar dist.	53 38 45.23
	° ′ ″				
Star's alt. ...	59 59 30				
Latitude ...	13 11 45	Log. sec ...	10.0116214		
Polar dist. ...	53 38 45.23	Log. cosec ...	10.0940052		
2)	126 50 00.23				
Half sum ...	63 25 00.11	Log. cosin ...	9.6507915	Log. cos decl.	= 9.9059948
Altitude ...	59 59 30.00			Log. sin H.A.	= 9.5598473
		Log. sin ...	8.7762819	Log. sec alt	=10.3009206
½ S-A	03 25 30.11	Log. sin sq. ...	38.5327000	Log. sin az.	= 9.7667627
		Log. sin ½ H.A.	9.2663500		
			° ′ ″		° ′ ″
		Half H.A. ...	10 38 26.69	Az.	=35 45 56.24
		Therefore H.A.	=21 16 53.38		
			h. m. s.		
		21°	= 1 24 00		
		16m.	= 1 04		
		53.38s.	= 3.55		
		And H.A. in T.	= 1 25 07.55		
		Star's R.A.	=13 16 44.47		
		R.A. meridian	=14 41 52.02		
		L.S.T. of L.M.N.	=15 32 38.60		
		Sid. Int. from L.M.N.	=11 09 13.42		
		M.T.Eq. h.	10 58 11.87		
		M.T.Eq. m.	8 58.53		
		M.T.Eq. s.	13.38		
		Calc. L.M.T. ...	11 07 23.78		
		G.M.T. of pass	9 16 33.23		
		Long. in time	1 50 50.55		
		Long. in arc ...	27 42 38.25		

L.M.T. & LATITUDE FROM ALTITUDES OF STARS WITH A PRISMATIC ASTROLABE.

Name of Star α Pyx. Photo No. 03830. Station AC13.

	° ′ ″		h. m. s.
Approx. lat. ...	13 11 45S.	Approx long. ...	1 51 20E.
	h. m. s.		
Chron. time ...	5 02 05		
Stop watch ...	6.2		
Time of pass	5 01 58.8		
Chron. error ...	6 35.01		
G.M.T. of pass	4 55 23.79		
	° ′ ″		
Star's alt. ...	59 59 30		
Latitude ...	13 11 45	Log. sec ...	10.0116214
Polar dist. ...	57 03 36.88	Log. cosec ...	10.0761125
	2) 130 14 51.88		
Half sum ...	65 07 25.94	Log. cosin ...	9.6239290
Altitude ...	59 59 30		
½ S.A.	05 07 55.94	Log. sin ...	8.9516005
		Log. sin sq. ...	38.6632634
		Log. sin ½ H.A.	9.3316317
		° ′ ″	
		Half H.A. ...	12 23 51.56
		Therefore H.A. =	24 47 43.12
			h. m. s.
		24° =	1 36
		47m. =	3 08
		43.12s. =	2.88
		And H.A. in T. =	1 39 10.88
		Star's R.A. =	8 40 49.02
		R.A. meridian =	10 19 59.90
		L.S.T. of L.M.N. =	15 32 38.60
		Sid. Int. from L.M.N. =	6 47 21.30
		M.T.Eq. h.	5 59 01.02
		m.	46 52.30
		s.	21.24
		Calc. L.M.T. ...	6 46 14.56
		G.M.T. of pass	4 55 23.79
		Long. in time	1 50 50.77
		Long. in arc ...	27 42 41.55

	h. m. s.
R.A. Star ...	8 40 49.02
	° ′ ″
	90 00 00
Star's decl. ...	32 56 23.12
Star's polar dist.	57 03 36.88
Log. cos decl.	= 9.9238877
Log. sin H.A.	= 9.6226054
Log. sec alt.	= 10.3009206
Log. sin az.	= 9.8474137
	° ′ ″
Az.	= 44 43 40.89

L.M.T. & LATITUDE FROM ALTITUDES OF STARS WITH A PRISMATIC ASTROLABE.

Name of Star α Leo. Photo No. 03830. Station AC13.

		° ′ ″		h. m. s.		
Aprox. lat.	...	13 11 45S.	Approx. long. ...	1 51 20E.	Date 16/5/31.	
		h. m. s.				h. m. s.
Chron. time	...	5 50 25			R.A. Star	... 10 04 43.02
Stop watch	...	6.1				° ′ ″
						90 00 00
Time of pass	...	5 50 18.9				
Chron. error	...	6 35.16				
G.M.T. of pass		5 43 43.74				
		° ′ ″				
Star's alt.	...	59 59 30				
Latitude	...	13 11 45	Log. sec	... 10.0116214	Star's decl.	... 12 18 17.69
Polar dist.	...	102 18 17.69	Log. cosec	... 10.0100933	Star's polar dist.	102 18 17.69
		2) 175 29 32.69				
Half sum	...	87 44 46.34	Log. cosin	... 8.5946776		
Altitude	...	59 59 30				
½ S-A	...	27 45 16.31	Log. sin	... 9.6680919		
			Log. sin sq.	... 38.2844842	Log. cos decl.	= 9.9899067
					Log. sin H.A.	= 9.4392533
			Log. sin ½ H.A.	9.1422421	Log sec alt.	= 10.3009206
				° ′ ″	Log. sin az.	= 9.7300806
			Half H.A.	... 7 58 32.49		° ′ ″
			Therefore H.A.	= 15 57 04.98	Az.	= 30 29 18.88

	h. m. s.
15° =	1 00 00
57m. =	3 48
04.98s. =	0.33
And H.A. in T. =	1 03 48.33
Star's R.A. =	10 04 43.02
R.A. meridian =	11 08 31.35
L.S.T. of L.M.N. =	15 32 38.60
Sid. Int. from L.M.N. =	7 35 52.75
M.T.Eq. h.	6 58 51.19
M.T.Eq. m.	34 54.27
M.T.Eq. s.	52.61
Calc. L.M.T. ...	7 34 38.07
G.M.T. of pass	5 43 43.74
Long. in time	1 50 54.33
Long. in arc ...	27 43 34.95

L.M.T. & LATITUDE FROM ALTITUDES OF STARS WITH A PRISMATIC ASTROLABE.

Name of Star ε Viv. Photo No. 03830. Station AC13.

	° ′ ″		h. m. s.
Approx. lat. ...	13 11 45S.	Approx. long. ...	1 51 20E.
	h. m. s.		
Chron. time ...	8 49 55		
Stop watch ...	6.1		
Time of pass ...	8 49 48.9		
Chron. error ...	6 35.68		
G.M.T. of pass	8 43 13.22		
	° ′ ″		
Star's alt. ...	59 59 30		
Latitude ...	13 11 45	Log. sec ...	10.0116214
Polar dist. ...	101 19 37.49	Log. cosec ...	10.0085426
	2) 174 30 52.49		
Half Sum ...	87 15 26.24	Log. cosin ...	8.6798895
Altitude ...	59 59 30		
½ S-A	27 15 56.24	Log. sin ...	9.6609759
		Log. sin sq. ...	38.3610294
		Log. sin ½ H.A.	9.1805147
			° ′ ″
		Half H.A. ...	8 42 57.34
		Therefore H.A. =	17 25 54.68

		h. m. s.
	17° =	1 08 00
	25m. =	1 40
	54.68s. =	3.65
And H.A. in T. =		1 09 43.65
Star's R.A. =		12 58 46.40
R.A. meridian =		14 08 30.05
L.S.T. of L.M.N. =		15 32 38.60
Sid. Int. from L.M.N. =		10 35 51.45
M.T.Eq.	h.	9 58 21.70
	m.	34 54.27
	s.	51.31
Calc. L.M.T. ...		10 34 07.28
G.M.T. of pass		8 43 13.22
Long. in time		1 50 54.06
Long. in arc ...		27 43 30.9

Station AC13.
Date 16/5/31.

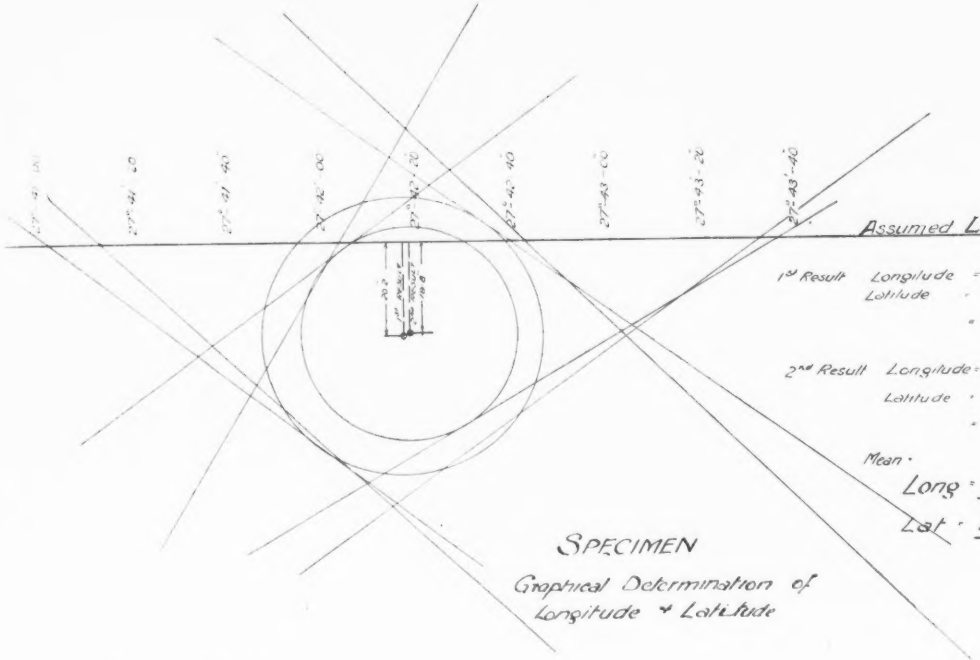
	° ′ ″
R.A. Star ...	12 58 46.40
	h. m. s.
	90 00 00
Star's decl. ...	
Star's polar dist.	101 19 37.49
Log. cos decl. =	9.9914574
Log. sin H.A. =	9.4765003
Log. sec alt. =	10.3009206
Log. sin az. =	9.7688783
	° ′ ″
Az. =	35 58 02.65

L.M.T. & LATITUDE FROM ALTITUDES OF STARS WITH A PRISMATIC ASTROLABE.

Name of Star π Hyd. Photo No. 03830. Station AC13.

	° ′ ″		h. m. s.		
Approx. lat. ...	13 11 45S.	Approx. long. ...	1 51 20E.	Date 16/5/31.	
	h. m. s.				h. m. s.
Chron. time ...	6 49 10			P.A. Star ...	14 02 28.17
Stop watch ...	5.4				° ′ ″
					90 00 00
Time of pass	6 49 04.6				
Chron. error ...	6 35.33			Star's decl. ...	26 21 19.42
G.M.T. of pass	6 42 29.27			Star's polar dist.	63 38 40.58
	° ′ ″				
Star's alt. ...	59 59 30				
Latitude ...	13 11 45	Log. sec ...	10.0116214		
Polar dist. ...	63 38 40.58	Log. cosec ...	10.0476642		
	2) 136 49 55.58				
Half sum ...	68 24 57.79	Log. cosin ...	9.5656874	Log. cos decl	= 9.9523360
Altitude ...	59 59 30			Log. sin H.A.	= 9.6825945
				Log. sec alt.	= 10.3009206
$\frac{1}{2}$ S-A	08 25 27.79	Log. sin ...	9.1658495		
		Log. sin sq. ...	38.7908225	Log. sin az.	= 9.9358511
		Log. sin $\frac{1}{2}$ H.A.	9.3954112		
			° ′ ″		° ′ ″
		Half H.A. ...	14 23 29.91	Az.	= 59 37 08.94
		Therefore H.A. =	28 46 59.82		

	h. m. s.
28° =	1 52 00
46m. =	3 04
59.82s. =	3.82
And H.A. in T. =	1 55 07.82
Star's R.A. =	14 02 28.17
R.A. meridian =	12 07 20.35
L.S.T. of L.M.N. =	15 32 38.60
Sid. Int. from L.M.N. =	8 34 41.75
M.T.Eq. h.	7 58 41.36
m.	33 54.43
s.	41.64
Calc. L.M.T. ...	8 33 17.43
G.M.T. of pass	6 42 29.27
Long. in time	1 50 48.16
Long. in arc ...	27 42 02.40


Assumed Latitude 13°-11'-45"
1st Result Longitude = 27°-42'-16"
Latitude = 13-11-45 + (20.2" x cos lat.
= 13°-12'-04".65
2nd Result Longitude = 27°-42'-17".5
Latitude = 13-11-45 + (19.8 cos lat)
= 13°-12'-04".26
Mean · Long = 27°-42'-16".75
Lat = 13°-12'-04".45

SPECIMEN

Graphical Determination of Longitude & Latitude

POINT AC 13

PROGRAMME OF STARS.

Bar. Start: Mid: End: Photo No. 03830. Station AC13.

Date: 16 May, 1931. Temp. Start: 62.5°F. Mid: 59°. End: 57.5°F.

Approx. Azimuth. °	Quad.	Approx. L.S.T. h. m. s.	Mag.	Star.	Chron. h. m. s.	Stop Watch. Seconds.	Approx. Obs. Azimuth. ° ′ ″	Remarks.
147	N.W.	9 59 30	4.3		4 41 45	6.4	146 01 58	6—34.96
240	N.E.	10 03 30	3.8		4 45 25	8.2	238 41 30	6—34.97
217	N.E.	10 09 30	4.9	*	4 50 35	9.2	215 33 27	6—34.98
229½	N.E.	10 13 30	4.2		4 54 50	5.8	227 02 54	6—35.00
44	S.W.	10 21 00	3.7	*	5 02 05	6.2	42 29 18	6—35.01
129	N.W.	10 24 00	3.3		5 06 00	6.5	127 22 28	6—35.03
145	N.W.	10 35 00	5.1		5 18 25	10.4	143 46 12	6—35.06
223½	N.E.	10 42 15	4.2	*	5 23 00	5.8	221 25 32	6—35.09
140¼	N.W.	10 53 00	3.8		5 35 10	7.9	138 51 51	6—35.11
148	N.W.	11 08 30	1.3	*	5 50 25	6.1	146 27 56	6—35.16
237¼	N.E.	11 12 45	3.7		5 54 25	4.9	235 37 45	6—35.17
134¾	N.W.	11 20 00	4.9		6 02 35	8.8	133 12 47	6—35.19
138½	N.W.	11 47 00	3.9		6 29 20	4.8	137 01 26	6—35.27
216	N.E.	11 50 00	3.0		6 31 00	7.3	214 42 12	6—35.28
324	S.E.	11 51 30	2.9	*	6 33 30	6.5	322 31 52	6—35.28
300	S.E.	12 07 30	3.5	*	6 49 10	5.4	298 47 12	6—35.33
34½	S.W.	12 16 30	4.7		6 58 20	7.3	33 06 29	6—35.36
129½	N.W.	12 49 00	4.1		7 30 55	12.3	127 54 51	6—35.45
136¾	N.W.	13 22 00	4.2		8 04 10	5.8	135 27 54	6—35.54
147½	N.W.	14 05 30	3.0	*	8 49 55	6.1	146 12 10	6—35.68
300¼	S.E.	14 30 30	1.2		9 11 25	5.5	298 58 36	6—35.74
35½	S.W.	14 41 30	2.9	*	9 23 20	11.0	34 10 40	6—35.77

* Stars used in plot overleaf.

Construction of Transparent Plotting Grids

The plotting grids are diagrams representing the perspective view of imaginary squares on the ground taken by the camera, which is set in the mounting at an oblique angle. It is essential in this method of mapping that the apparent horizon is visible on the photographs and it must be assumed that the ground shown on each photograph is level.

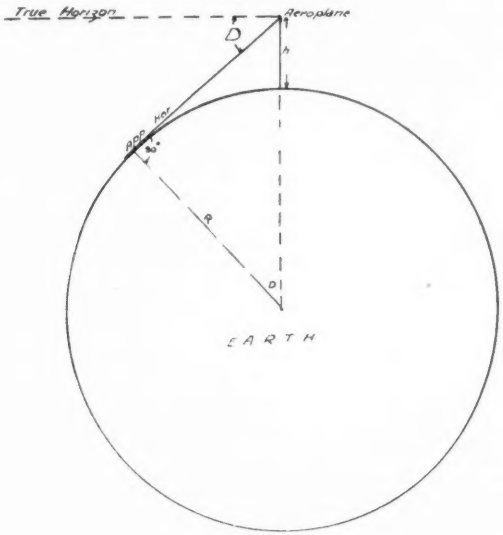


FIG. 1.

Referring to Fig. 1 the angle of *Dip* is the angle at the lens of the camera between the true and apparent horizons shown as D.

Angle D = angle A.

$$\therefore \tan D = PT/OT = \sqrt{(PO^2 - OT^2)}/OT = \sqrt{(2h/R - h^2/R^2)}$$

h^2/R^2 being very small can be neglected.

$$\therefore \tan D = \sqrt{(2h/R)} = \sqrt{(h/10{,}444{,}314)}.$$

D being a very small angle tan D can be written tan 1in.

$$\therefore Dip = \tan D/\tan 1\text{in.} = 206{,}265\sqrt{(h/10{,}444{,}314)} = 63.82\sqrt{h}.$$

Correcting for refraction in South Africa multiply this result by .936.

$$\therefore Dip \text{ in seconds} = 59.736\sqrt{h} \quad . \quad . \quad . \quad . \quad (1)$$

Example.—With an aeroplane operating at 10,000 feet the angle of *dip* is

$$59.736\sqrt{h} = 5973.6 \text{ secs.}$$
$$= 1^\circ\ 39'\ 33.6''.$$

Operating from a height of 10,000 feet with a 7in. lens the most suitable angle of depression is 24° to the horizontal. On a 7in. square photograph the position of the horizon will be shown approximately .34in. from the edge, and this distance of .34in. will give sufficient latitude for a forward tilt of almost 4°, making the depression angle 28° at which the apparent horizon is just off the photograph.

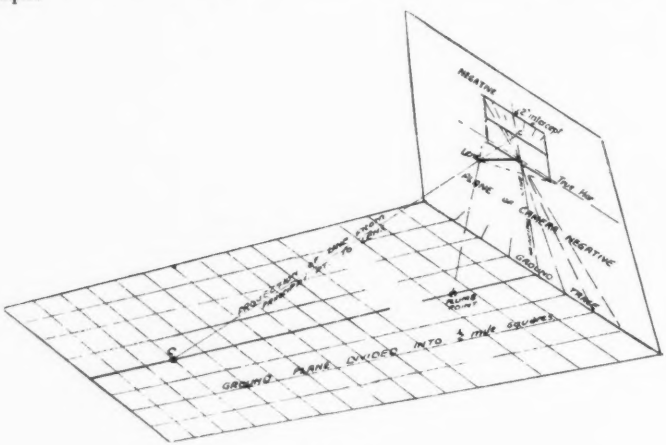


FIG. 2.

In order to appreciate what is actually required in the construction of a grid, Fig. 2 is drawn to represent the ground plane (shown level) and the negative plane. The centre of the photograph, commonly known as the principal point, is shown at C and the corresponding detail on the ground is at P.

A good piece of Bristol board and a very sharp pencil should be used in the construction of the grid to ensure accuracy. First draw the principal line HS as shown in Fig. 3, and a short line at right angles to the principal line through H will represent the true horizon and, incidentally, the vanishing point of all lines parallel to the principal line. Call this point O. From O along the principal line, mark off a distance $OC = f \tan \theta$,

where θ = angle of depression.
f = focal length of the lens.
Then $f \tan \theta = 7.04 \tan 24^\circ$
$= 3.13$ inches . . . . . (2)

From O along the principal line set off distance OS representing the distance from the true horizon to the ground trace.

$$OS = h \sec \theta/\text{scale}.$$

When 2 inches along the ground-trace, in the plane of the negative, represents $\frac{1}{2}$ mile, then

$$OS = h \sec O/1{,}320 \text{ inches}.$$
$$= 8.29 \text{ inches} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

From O then set off OS equal to the above amount and through S draw a line parallel to the apparent horizon. From S on either side set off distances equal to 2 inches and from each of these divisions draw lines to O. In order to complete the grid, the $\frac{1}{2}$ mile divisions at right angles to these are constructed

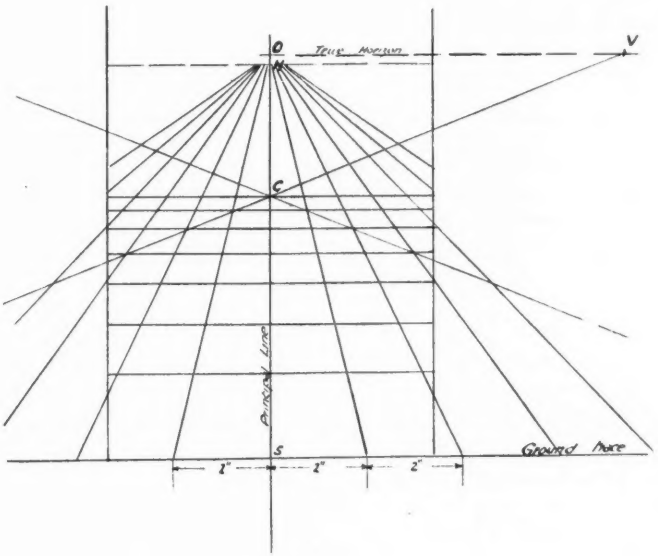


FIG. 3.

from the diagonals of the half mile squares. The vanishing point of all diagonals is found along the true horizon line at a distance from O of $f \sec \theta$ inches. In Fig. 3 these points are shown as V and V'.

$$\therefore HV \text{ and } HV' = f \sec \theta$$
$$= 7.04 \sec 24^\circ$$
$$= 7.71 \text{ inches} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

From V and V' draw VC and $V'C$ and produce both to intersect the ground trace line. Parallel lines to the horizon are then drawn through the intersections of the radial lines with the diagonals. In order to simplify the graphical construction of the grid a line drawn parallel to the horizon through a point half way between H and S would have divisions 1in. apart; similarly, a line drawn through a point one quarter of the distance HS from H would have divisions $\frac{1}{2}$in. each.

Fig. 4 shows the complete construction of a grid for a depression angle of 23° and an altitude of 10,000 feet. The heavy margin line represents the actual size of the xylonite grid required and provides a clear margin all round to prevent the grid cracking or splitting along the cut lines. Clear sheet xylonite about ten thousandths thick is the most suitable material and the lines should be cut very lightly with a sharp knife and not scratched with a needle. The cut lines are afterwards filled with some black ink or other opaque material. The notch shown at the top of the grid is for the purpose of being able to handle and orient the print.

Table 1 gives the distances from the apparent horizon to the principal point on the photograph for various angles of depression. It is, therefore, convenient to make a template on xylonite containing this information as shown in Fig. 5. This template, often known as the grid finder, is placed on the photograph so that the line representing the apparent horizon coincides with the apparent horizon on the photograph and the required grid for that particular photo can be read off the scale on the principal line.

When using transparent grids the following rule must be strictly adhered to. Select the nearest grid (grids for the Northern Rhodesian contract were made for every half degree between 19° and 28°) place *C* of the grid on the principal point of the photograph and orient the grid about this point until the apparent horizons are either coincidental or parallel to each other.

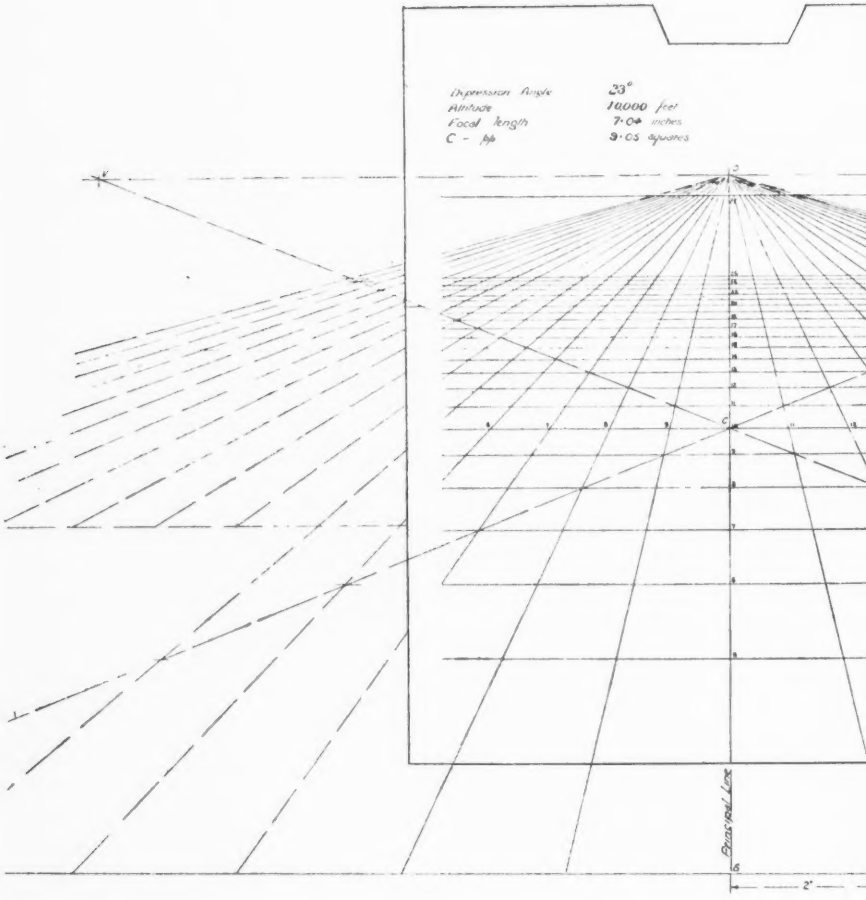
In order to save a considerable amount of time in the mapping operations, the information on each photograph which is to be mapped should be lined out in ink. The draughtsman can then concentrate on the mapping and be assured that (*a*) he will be plotting all the necessary information and (*b*) the topographical features in the overlapping prints have been accurately inked in to agree with one another.

Mapping Operations

The vertical photographic control strips are the first to be plotted, as they are traverses between the control points and control the scale of all the intermediate oblique strips. When traversing the photographs the "Centre Point" method is sufficiently accurate, provided sufficient care is taken to correct for variations in height. As previously mentioned, the maximum amount of error in azimuth for 35 contact photographs should not exceed ¼in. and as this amount is reduced to about 1/50th in. in the scale of the final plot it is unnecessary to employ more accurate methods of traversing such as the "Arundel Method."

The operations are taken in the following order:—

1. Mark the position of all control points on the vertical photographic strips.
2. Arrange, in separate batches, each set of vertical photographs between adjacent control points.
3. Transfer the centre point of each photograph on to the overlapping portion of the two adjacent prints. This operation can be carried out by means of a stereoscope or by the intersection of three arcs taken from clearly identified points of detail in the vicinity of the centre point. It is important when marking these points that only the very smallest hole, made with a very sharp needle, is necessary.
4. Each print now having its own principal point and the transferred positions of the two adjacent principal points, straight lines scratched with a sharp needle are drawn through all adjacent points in numerical order. In order to ensure greater accuracy in the traversing, all these lines must be produced to the edges of the prints and it is further advisable to break each line in the vicinity of the principal points so that these points are not obscured and can be referred to at any time.


Depression Angle 23°
Altitude 10000 feet
Focal length 7·04 inches
C - pp 3·05 squares
Picture Line

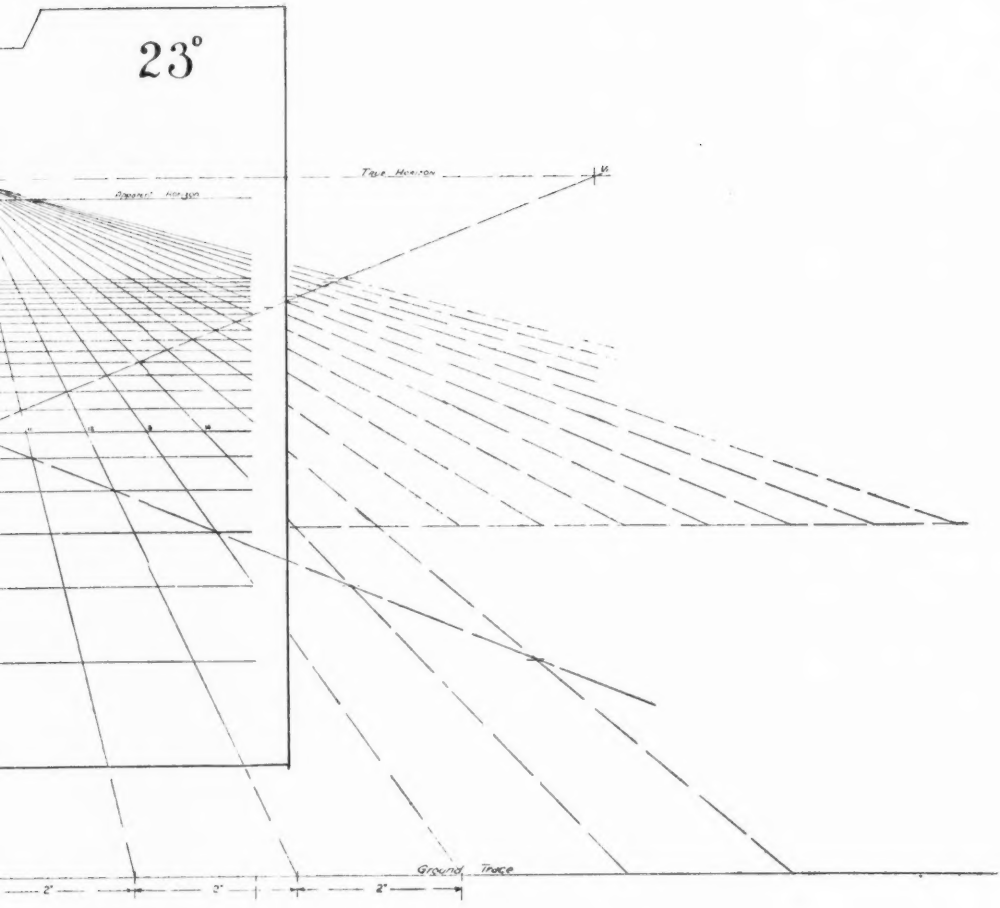


FIG. 4.

5. The base lines of the photographs are then traversed on one long continuous piece of tracing paper. If the aeroplane maintained approximately the same altitude and the ground was fairly level, contact prints can be used for traversing. Supposing, for instance, prints Nos. 22, 23, 24, 25 and 26 required traversing, the tracing paper is placed over print No. 22 on a glass-topped table which is illuminated from underneath, and a line is drawn through point 22 and 23 and extended four or five inches. On this line mark the principal points 22 and 23. Then take print 23 and place its principal point under the position obtained from print 22, orient the print so that the line 22 to 23 exactly coincides and then draw another line through 23 and 24 and extend, as before. Mark the position of 24, but before accepting it as the final position, see that the points 22 are coincidental. Supposing distance 22 to 23 on the tracing is 1/16th inch longer than on print 23, then point 24 will have to be extended along the base line 23 to 24 1/16th of an inch multiplied by the distance (23 to 24)/(22 to 23). This operation can be done graphically while traversing. Thus any minor scale errors are adjusted and the final traverse should be to a fairly constant scale.

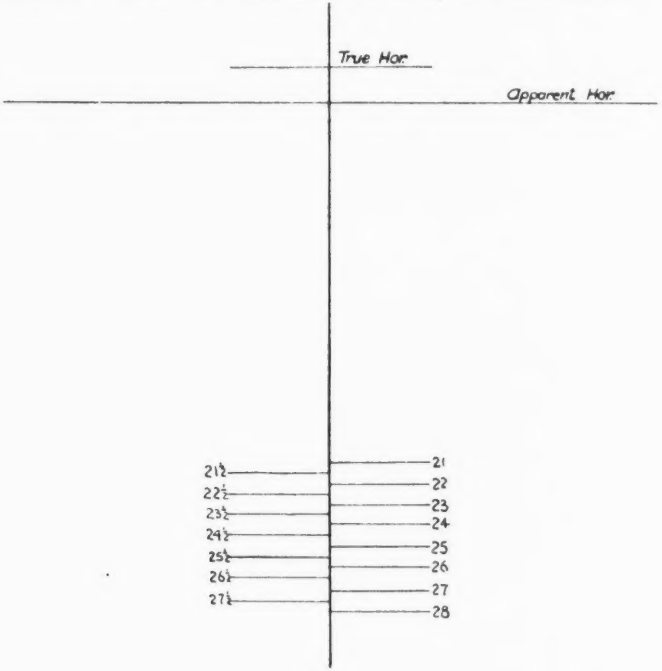


FIG. 5.

6. All the main topographical details such as roads, dambos (grassy plains or clearings in the dense bush, usually in the vicinity of a water course), railroads, paths, native villages, etc., are then traced from the photographs and the distance between the two control points is accurately measured.
7. These traverses are then reduced photographically to a scale of 1/125,000, being the scale of the original plot. Paper negatives are good enough for this operation and tracings of these are made and the information transferred to the projection sheets.

Oblique Photographs

The oblique photographic strips are then sorted into batches, each one extending from one control band to the other. Each batch is then divided into three separate batches containing (*a*) the centre photos (*b*) those taken from the right side and (*c*) those taken from the left side. The first operation is with the centre photographs or those taken along the path of the aeroplane but in the opposite direction to that of the flight.

As these photographs are taken in the same direction, the topography in the extreme foreground of one print can be quite easily recognised in three or four following centre photos and, therefore, it is a fairly simple operation to draw a straight line through the first photograph and transfer that line to all the other centre photographs in the same strip, by identifying points of detail through which the line passes on the previous print. This line, therefore, represents a straight line on the ground and, using this as the base for plotting, any tendency to accumulate errors in azimuth is obviated. When transferring this line from one print to another it is advisable to identify as many points as possible.

The next step is to select two points, one in each foreground corner of the print and such that they can be easily identified and marked in the following centre photograph. These points should not be nearer than $\frac{3}{4}$in. from the side

FIG. 6A.
Grid superimposed over oblique photo.

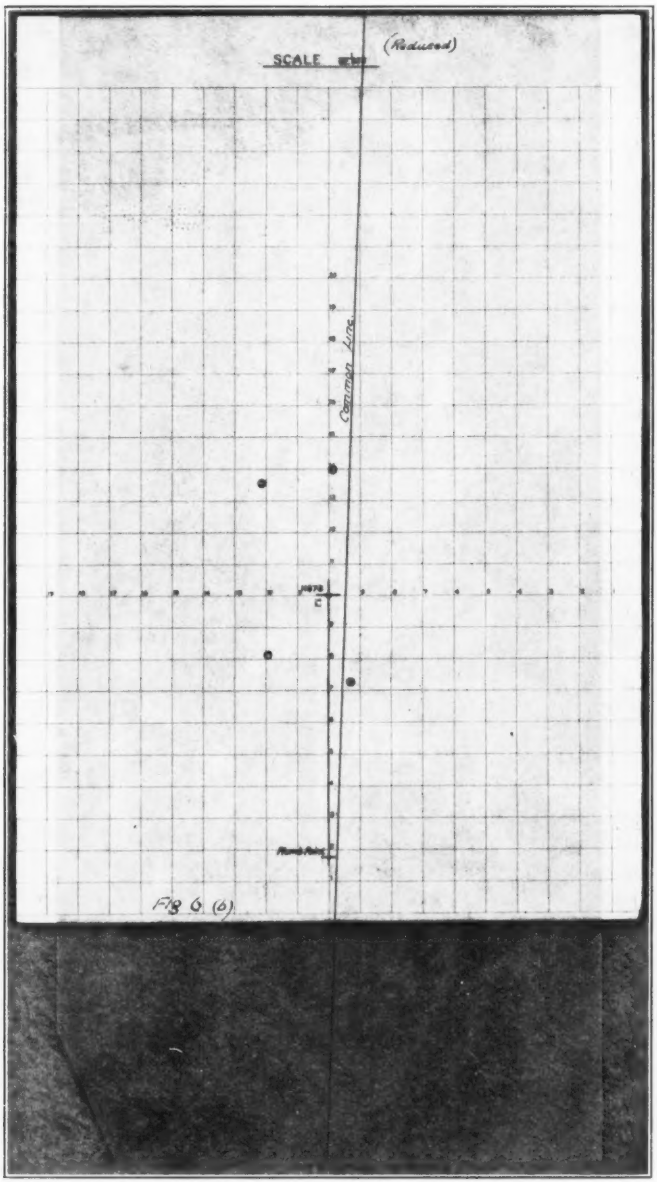


FIG. 6B.
First stage of skeleton traverse.

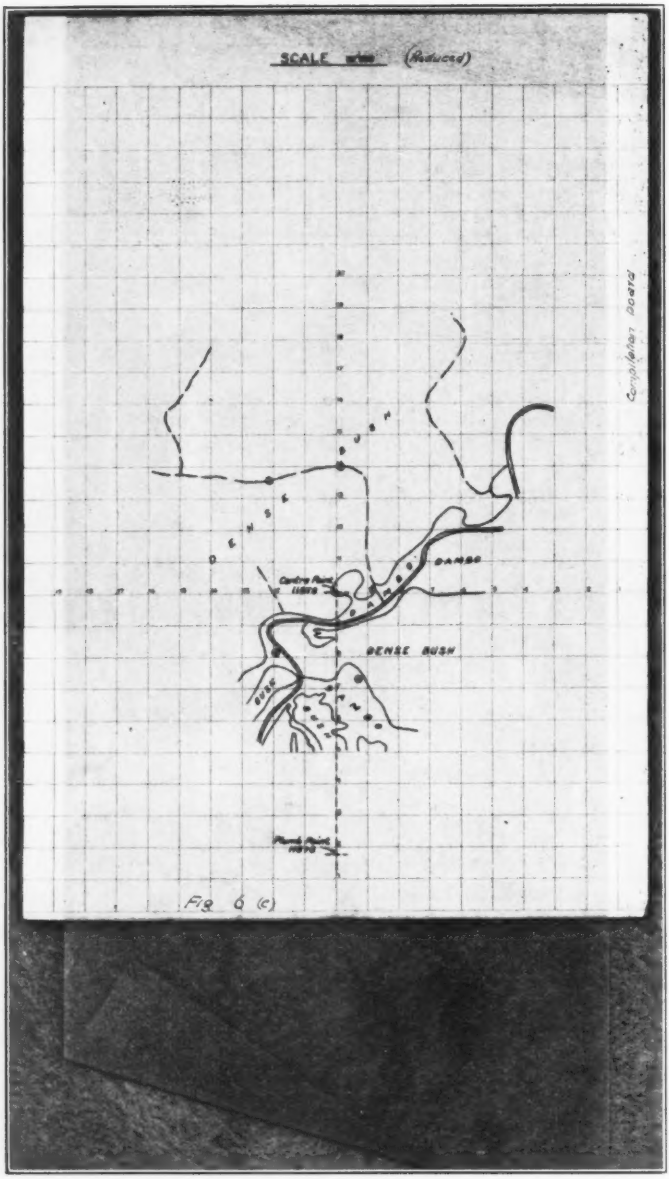


FIG. 6c.
Topographical detail.

or bottom edge of the print because points nearer the edge than this are likely to plot inaccurate owing to lens distortion. The centre photographs are now ready for the " skeleton traverse " which is a continuous plot of the prints in correct relation to each other, but showing only the centre point, plumb point and two common points of each photograph. The traversing is done on tracing paper over a compilation board which is divided into half-mile squares at a scale of 1/62,500 or 1in. = 5,280.33 feet. Fig. 6 shows a grid superimposed over a photograph and the plot on the compilation board.

To proceed with the skeleton traverse take a piece of tracing paper about 40in. long and 24in. wide. Draw a straight line down the centre of the paper and then place it over the compilation board so that the straight line passes accurately through the corresponding squares of the grid. Draw the principal line, mark the centre point and from this point along the principal line mark off a distance equal to the distance between the centre point and the plumb point of the aeroplane. This is obtained from the formula

$$C - pp = (h/\tan\theta)/\text{scale inches.}$$

In this case the scale being 1/62,500 the above could be written

$$(h/\tan\theta)/5208.33 \text{ or } h\cot\theta/5208.33 \quad . \quad . \quad . \quad (5)$$

For plotting purposes these distances in inches can more conveniently be written in terms of half mile squares at the required scale, enabling the draughtsman to set off the distance on the compilation board.

Before removing the tracing plot the position of the two common points in the foreground. The next centre oblique photograph is then placed under the required grid and the tracing replaced over the compilation board so that (*a*) the position of the straight line on the compilation board agrees with the line as shown under the grid and (*b*) the position of the points plotted from the foreground of the previous photograph now agree on the compilation board with the position of the same points as plotted from the following photographs. The line therefore checks for swing in azimuth and the points check for scale. When the line is in the correct position and at the same time the points plot in the same position from the second photograph as from the first, then the principal line, centre point, plumb point and the next two common points can be plotted. So the operation is repeated for each centre photograph from one band of vertical control photographs to the next. The reason for making a skeleton traverse without inserting the topographical detail is in order to check the position of the apparent horizon. It is quite a frequent occurrence that low lying haze will make the horizon appear to be either higher or lower and consequently the incorrect grid will be used. By means of the straight line and the common points the correct grid can be found and thereby a more accurate position of the apparent horizon established.

When all points agree join all consecutive plumb points. The resulting line will then represent the path of the aeroplane and the angle between the principal

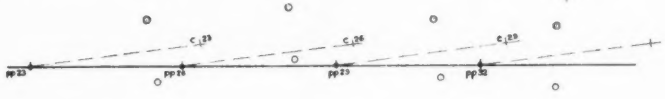


FIG. 7.

line of a photograph and the plumb line will represent the angle of drift. Fig. 7 shows a skeleton traverse with an angle of drift of about $7\frac{1}{2}$ degrees.

The next operation is to examine all the photos, including those taken from the sides, in order to ascertain the order of the taking and secondly the time interval between each exposure. Between each of the plumb points shown on the skeleton traverse two other plumb points for the side photographs are located

by fixing their position proportional to the time interval between exposures. For instance, if the time interval between two centre photographs was 120 seconds and the distance between the two plumb points on the skeleton traverse measured 3in., it is assumed that the aeroplane travelled at a constant speed and therefore at the rate of 1in. on the skeleton traverse for every 40 seconds.

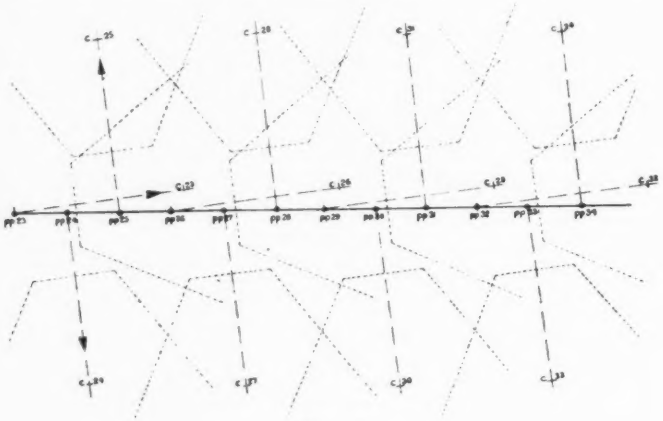


FIG. 8.

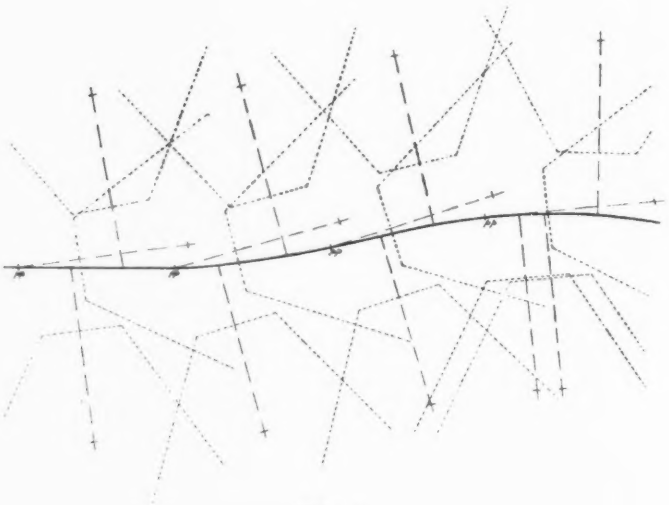


FIG. 9.

Suppose further that 45 seconds after the first centre photograph was taken the next oblique to the left side was exposed and 35 seconds later the right side oblique taken, then the positions of the plumb points of these photographs are located by measuring distances along the plumb line from the first centre plumb point equal to $(45/120) \times 3$ inches for the left side and $(80/120) \times 3$ inches for the right side.

When all the plumb points are thus located the principal lines for the side photographs are then drawn at right angles to the principal line of the nearest centre photograph, except when the aeroplane has altered its course, in which case the direction of the principal line of the side photograph is altered proportionately to the change in direction. Fig. 8 shows the positions of all photographs in a strip which has been flown on a straight course, and Fig. 9 illustrates the difference caused by a change in direction of flight.

All topographical detail is now plotted on the skeleton traverse from the centre photographs, while the detail of the side photographs is plotted on separate pieces of tracing paper. These side plots are then assembled under the centre traverse on to which all the additional topography is traced. Control points are marked and the reduction factor calculated to photographically reduce the traverse to the scale of the projection sheet, viz., 1/125,000.

For the purpose of making these reductions, paper negatives were considered sufficiently accurate and to save the cost and time of making prints, these negatives were traced direct and the plot was then transferred to the projection sheet with the aid of transfer paper. If the centre traverses have been carefully and accurately plotted there will be very little adjustment required between the separate completed strips during the final assembly.

Attached are plates showing a projection sheet on which the vertical control strips have been plotted and along which pick-up points for the oblique strips are marked. The other plate shows a completed sheet of one degree square.

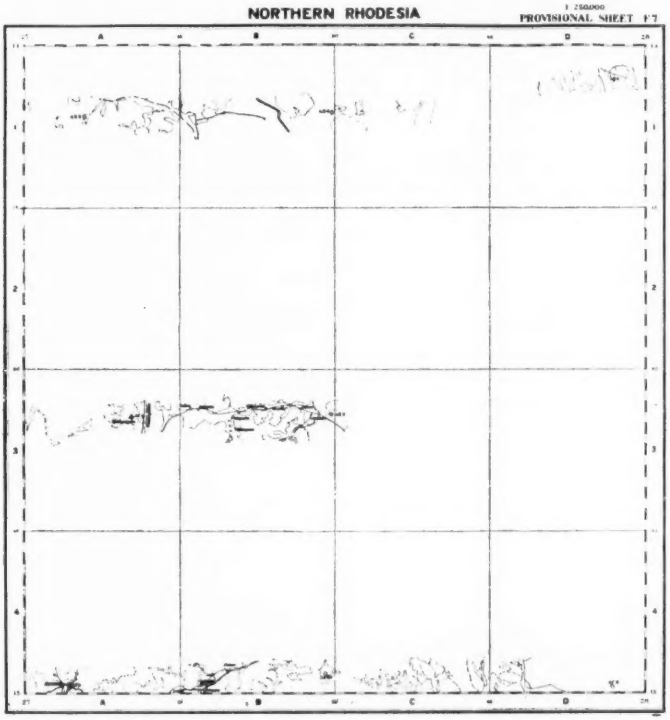


PLATE 4.
Vertical control strips.

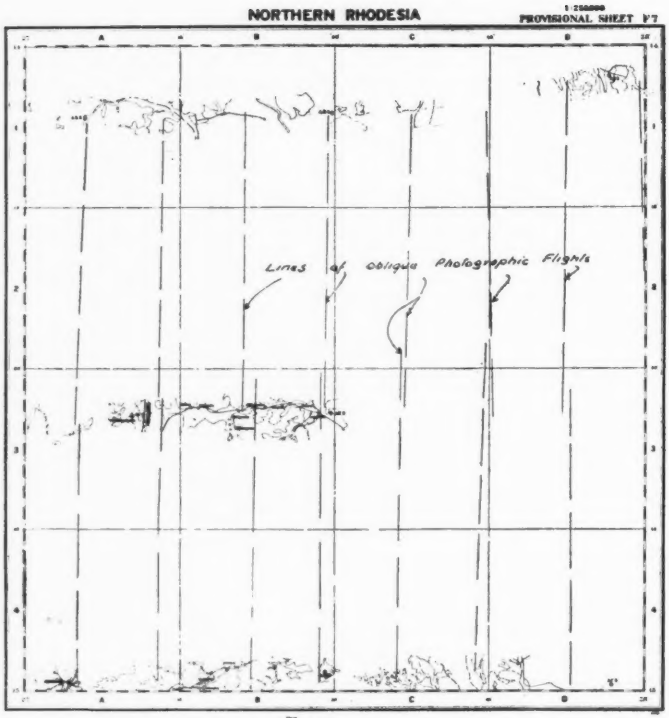


PLATE 4A.

Position of oblique photo strips.

TABLE.

DISTANCES OF PRINCIPAL POINT TO PLUMB POINT.

Giving equivalent distances in squares on compilation board at scale of 1/62,500.

Depression angle or grid for	Distance miles.	Distance squares.
28°	3·56	7·22
27½°	3·64	7·38
27°	3·72	7·55
26½°	3·80	7·72
26°	3·88	7·87
25½°	3·97	8·05
25°	4·06	8·24
24½°	4·16	8·45
24°	4·25	8·61
23½°	4·36	8·84
23°	4·46	9·05
22½°	4·57	9·27
22°	4·69	9·52
21½°	4·81	9·75
20°	4·93	10·00

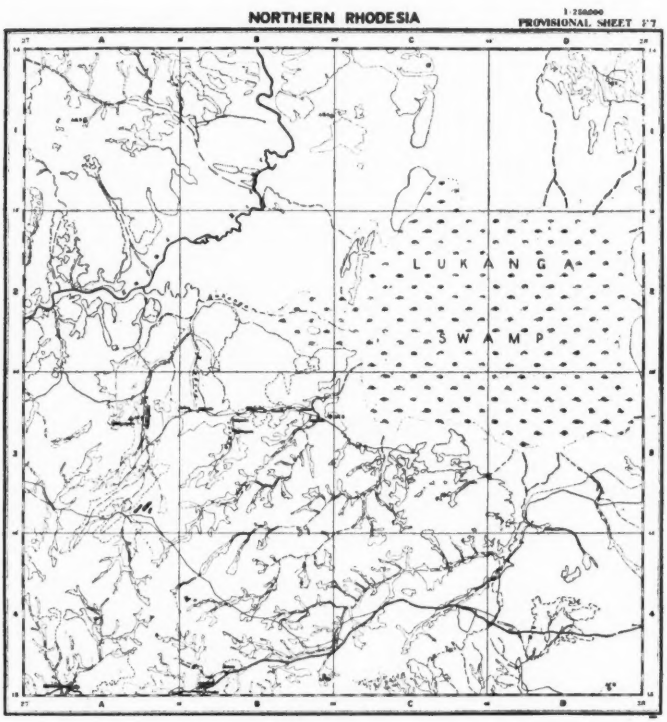


PLATE 4B.
Final sheet.

It must be remembered that this is not an accurate method of producing maps, but as a reconnaissance survey at a scale of 1/250,000, maps so compiled from oblique photographs should not contain errors exceeding one quarter of a mile between the control bands.

TABLE I.

DATA FOR PLOTTING GRIDS FOR ANGLES VARYING BETWEEN 22° AND 28°.

Angle of Depression.	O C	C H	O S	O V
22°	2.84	2.61	8.17	7·59
22° 30′	2.92	2.68	8.20	7.62
23°	2.99	2.75	8.23	7.65
23° 30′	3.06	2.82	8.26	7.68
24°	3.13	2.89	8.29	7·71
24° 30′	3.21	2.96	8.32	7·74
25°	3.28	3.04	8.36	7·77
25° 30′	3.36	3.11	8.39	7.80
26°	3.43	3.18	8.43	7.83
26° 30′	3.51	3.26	8.46	7.87
27°	3.59	3.33	8.50	7·90
27° 30′	3.66	3.41	8.54	7·94
28°	3·74	3.48	8.58	7·97

Data for above:—
Altitude (h) equals 10,000 feet.
Focal length (f) equals 7.04 ins.

CORRESPONDENCE

The Editor, THE JOURNAL OF THE ROYAL AERONAUTICAL SOCIETY.

Sir,—I was particularly interested in Lieut.-Commander Graham's article on " Safety Devices in Wings of Birds " in the January issue of the JOURNAL, and also in the comments and further matter contributed by Dr. Lachmann in the April number.

However, I think Dr. Lachmann's interpretation of the reason given for wing slots, when he states that " I do not believe for one moment they were meant to be a safety device ".is not quite correct.

Commander Graham gives two reasons for these slots. The first, under para. VIII, is to regain a sufficiently high aspect ratio in a wing of curtailed span, and the second explanation, given in the following paragraph, is to enable the primary feathers to twist individually during flapping flight where it is impossible for the short, broad wing to twist through so large an angle as would be requisite.

These explanations, taken together, appear to me to be quite sufficient. Dr. Lachmann states: " I am convinced that slots in birds' wings are of first importance for flapping flight," but I would suggest the following definition: Slots constitute a device for restoring efficiency to an abbreviated wing, whether used for soaring or flapping flight.

In endeavouring to prove this, I will also attempt to answer the last of Lieut.-Commander Graham's questions, where an analysis of a group of birds with a common characteristic is suggested, as I think the answer to the latter supplies the required explanation.

Four birds—the rook, red-legged partridge, short-eared owl, and common gull—are given as each weighing one pound.

Before proceeding further, I would like to mention that the comparison is not altogether fair since, although the species mentioned are *all of the same tare weight,* birds, like aeroplanes, are capable of carrying loads so that their *all-up weights are not necessarily equal.*

For instance, the gull carries small fish, weighing a few ounces, the owl mice and similar vermin, the rook quite heavy twigs (for nest building), walnuts, etc., whilst the partridge, so far as I am aware carries little else but grain—and even then rises very little above the ground. If they are now placed in order of their loaded weight we should probably get the following: Owl, gull, rook, partridge, and as this is also the order of wing area the apparent discrepancies become somewhat diminished. A list of birds, which includes a column for all-up weight, would be of considerably greater value than one giving tare weight alone.

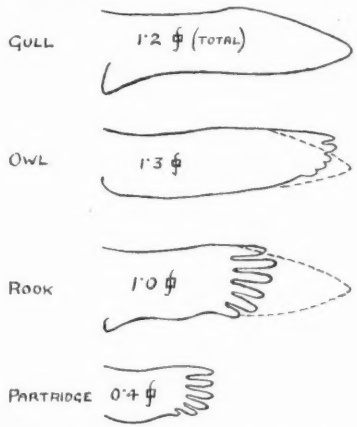
Nevertheless, for the present purpose, it is near enough to assume the four birds to be of equal weight.

The shape of a bird's wing, as pointed out in Commander Graham's paper, depends solely on the mode of living and the nature of its nesting place. The seagull, which spends its whole time in open spaces, has, what I would term, the ideal wing shape, that is a long, tapering wing of good aspect ratio (more than five) and completely unslotted. The wing loading, of just under one pound per square foot, is suitable to enable a bird of that size to soar efficiently, and the wing can support a heavier load in flapping flight.

The owl comes next, with about the same wing area, but of a little less span, compensated by being slightly slotted (combined slot factor 0.21). The comparatively large wing in this case is partly for supporting a greater load when carrying food, but of far greater importance, to ensure slow flapping for quietness when out in search of prey. Were it not for this factor the wings would probably be of shorter span for flight in the neighbourhood of trees.

Next comes the rook, with a wing area not much less than the gull, but of only two-thirds span for flight among trees. To make soaring flight possible the wings are heavily slotted (factor 1.3). However, this substitute for span does not give the high soaring performance of the gull.

Lastly comes the partridge, with a wing area only one-third that of the gull. It is certain that very little reduction of this area would make flight impossible, although experiments have shown that quite large amounts may be removed from other birds' wings before sustentation becomes impossible.



In order to be able to fly up, almost vertically, from long grass, etc., the wing span has to be very short indeed, and of course heavily slotted (factor 1.16). Consequently, the wing-beats have to be very rapid and the speed of flight great. Quick acceleration is inevitable and flight appears very laboured.

It is quite evident that the rook could carry out flapping flight with the slots closed in, as it would still be at least as efficient a wing as, for instance, that of the woodpigeon, but it is certainly doubtful whether the partridge would meet with the same success, which tends to show that slots are not provided for the purpose of flapping flight alone.

Further support to this contention is supplied by the birds of India, South America, and Africa, such as turkey buzzards, vultures, etc., all well slotted and which are capable of flapping flight only with difficulty unless aided by ascending currents of air.

One further point concerning the wrist-slot, of which Dr. Lachmann writes: " I am firmly convinced that this is a useless appendage." An examination will reveal that those birds having wings of ideal shape, as previously defined, swallows, gulls, etc., are devoid of wrist-slots, which means that it would be a useless appendage in their case, whereas in all instances where wings are of curtailed span this device has to be resorted to in order to bring the performance of an otherwise inefficient wing to as near that of the ideal shape as possible.

C. H. LATIMER NEEDHAM.

REVIEWS

The Mechanics of Flight

A. C. Kermode. Gale and Polden. 8/6 net.

This book is the first volume of a series of technical works intended for those aircraft apprentices, pilots, draughtsmen, etc., who are desirous of learning as much as possible about aeronautics without learning some calculus first. It is a very well written book and it contains an immense amount of practical information on all the primary aeronautical subjects, such as the atmosphere and resistance, aerofoils, aircraft flight, airscrews, etc. This information is well and clearly set out and should be easily grasped by those for whom it is intended. Books of this class fulfil a most useful purpose in educating those who would be frightened by mathematical symbols, however simply they may be used.

There are one or two matters which should be attended to in future editions. For instance, in the curve given on page 109 an aircraft speed at nearly the lowest resistance of the aircraft is called the "cruising speed." This is not the cruising speed as usually understood, which latter would be much higher, and the use of the term here is misleading. It is also not certain whether it will be the most economical speed at which to fly, as this will—leaving wind speed out of the question—also depend on the engine fuel consumption curve.

When discussing the question of manœuvrability in connection with the biplane and monoplane, it should be pointed out that the rigidity of the biplane construction is of great importance from this point of view. There should also be a reference in the airscrew section to the importance of seeing that the blades of the airscrew track properly and the cause of the vibration which will arise if the blades do not track should be explained.

The book contains a large number of diagrams and photographs which are well selected and clearly printed, and they add much to its value. It can be thoroughly recommended.

Illustrierte Technische Wörterbücher

A. Schlomann.

This is a technical dictionary giving equivalent terms in English, German, French, and Italian, and is certainly the best dictionary dealing with the aircraft technical terms in these four languages which has so far been published. It probably contains a larger number of words than any similar dictionary, and the tests which it has been possible to apply have not revealed any lapses in this direction, though they have revealed the existence of a few errors which are almost unavoidable in the first edition of a work of this kind.

It is thoroughly up to date, containing references to slotted wings as well as to other modern developments, and is arranged so as to make reference easy. This arrangement is not, however, obvious at first sight, and the book should contain an explanation of it. It also contains a large number of line illustrations of various aircraft and other parts and diagrams, which are cross-referenced to the letterpress so that an actual diagram of the part referred to can frequently be consulted.

The dictionary can be thoroughly recommended as being the best work of its kind in existence.